# ADAPTIVE FUNCTIONS OF METER IN MULTIPART MUSICAL RHYTHM

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I hereby declare that this submission is my own work and to the best of my knowledge it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at UNSW or any other educational institution, except where due acknowledgement is made in the thesis. Any contribution made to the research by others, with whom I have worked at UNSW or elsewhere, is explicitly acknowledged in the thesis.

I also declare that the intellectual content of this thesis is the product of my own work, except to the extent that assistance from others in the project's design and conception or in style, presentation and linguistic expression is acknowledged.

......................................................................

In memory of Blair Munro (trombonist, linguist, and famous prankster)

who would have done a better job

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Who scans the selfsame lines as they unroll,
Bestowing life, and quickening, rhythmic motion?
Who calls each single voice to celebrate the whole,
So all may blend in musical devotion?

*Goethe's Poet from Faust*

# Abstract

This dissertation investigates the processes involved in human attention to multipart musical rhythmic textures - such as those arising through the interaction of separate instrumental parts in musical ensembles. It is argued that efficiency in both the processing and representation of multipart rhythm is facilitated by *metric frameworks* generated by the attender. This efficiency is especially beneficial in multipart musical interactions because it enables the attentional flexibility that is required to attend simultaneously to a particular 'high priority' integrant pattern (e.g., a performer's own part) and the overall aggregate texture. A survey-based study conducted with practising ensemble musicians revealed that this attentional strategy - termed *prioritised integrative attending* - is generally considered to be optimal in a wide variety of ensemble settings.

The role of metric frameworks in promoting processing and representational efficiency was examined experimentally (using specially constructed sets of stimulus patterns) in both singlepart and multipart rhythmic contexts. Singlepart Experiments 1 and 2 employed auditory inspection time as an index of processing efficiency, and complexity judgements and context effects as indices of representational efficiency. In support of the current conception of the dual role of meter, the findings suggest that metrical patterns are both processed and represented more efficiently than nonmetrical patterns.

Novel dual task paradigms were developed and used in three multipart experiments to examine how this efficiency enables attentional flexibility in situations that demand prioritised integrative attending. Multipart Experiments 1 and 2 employed recognition memory paradigms to examine the effects of encoding and retrieving metrical versus nonmetrical integrant patterns upon the processing of the aggregate textures in which they were embedded. Multipart Experiment 3 simulated the demands of ensemble performance more closely in a paradigm requiring pattern reproduction. Overall results indicate that greater

intereference to prioritised integrative attending is produced by nonmetrical than metrical patterns.

A theory of Attentional Resource Allocation in Musical Ensemble Performance (ARAMEP) is proposed to account for the survey results and experimental findings. The central claim in ARAMEP is that metric framework generation allows attentional resources to modulate in a manner that is conducive to prioritised integrative attending. Thus, metric frameworks function adaptively to facilitate complex musical interactions.

# Table of Contents

# CHAPTER 2

## CHAPTER 4

## CHAPTER 7

## REFERENCES

# List of Tables

# List of Figures

# List of Appendices

# List of Tracks on Compact Disc

## Examples for Chapter 1



## Examples for Chapter 2



## Examples for Chapter 3

## Examples for Chapter 4



## Examples for Chapter 5

## Examples for Chapter 6



## Bonus Track

# CHAPTER 1

## APPROACHES TO ADAPTIVENESS AND RHYTHMIC BEHAVIOUR

This chapter highlights the benefits of examining musical rhythmic behaviour from the perspective of ecological adaptiveness. Various theoretical approaches to rhythm are reviewed in terms of their ecological validity. It is argued that considerations of adaptiveness necessitate the extension of these models to account for behaviour in multipart rhythmic contexts, and have implications for the role of musical meter.

# 1.1 Adaptiveness and rhythm

## 1.1.1 Ecological approaches

In some ways, musical activities - including those related to the perception and production of musical rhythm - are as common as activities associated with eating and drinking. These ubiquitous behaviours share a foundation in regulatory mechanisms that have presumably evolved to facilitate interactions between individuals and their environments. To assign regulatory bases to such behaviours is consistent with recommendations, made by researchers working in numerous diverse fields, that the behaviour of both human and non-human animals be considered from the perspective of ecological adaptiveness.

*Ecological adaptiveness* refers to the degree to which an organism's behavioural repertoire is optimally suited to its environment. Ecological approaches have been applied to the investigation of many forms of organismic behaviour, ranging from those that are traditionally believed to be relatively routine and accessible, such as eating (e.g., Woods, 1991) and sickness (e.g., Hart, 1988), to those that are more mysterious, such as visual and auditory perception (e.g., Bregman, 1981; Gibson, 1966, 1979; Marr, 1982), and cognitive functioning (e.g., Pylyshyn, 1984; Anderson, 1990).

However, assignment of adaptive value to a particular behaviour is not always a clear cut issue. In some cases, the process of distinguishing between adaptive and maladaptive forms of behaviour may lead to classifications that seem counterintuitive. For instance, Woods (1991) warns of potential dangers associated with the disruptive effect that eating (a necessary, and usually rewarding, behaviour) has on the homeostasis of an organism's internal environment. As another example, Hart (1988) describes how behaviours associated with sickness (i.e., lethargy, depression, and anorexia), which are typically considered maladaptive, are in fact adaptive in the sense that they facilitate the febrile response that combats infections.

Of course, links with basic regulatory mechanisms are more likely to be traceable in the case of eating and sickness related behaviours, than in other relatively sophisticated (in an evolutionary sense) behaviours, as the former are known to be driven largely by processes that originate in well studied subcortical brain regions (Stricker, 1990). Nevertheless, recent trends in the development of theories about perception and cognition suggest that behaviours associated with higher cortical functioning are likewise amenable to ecological approaches.

Theory builders, such as Marr (1982) in visual perception, and Pylyshyn (1984) and Anderson (1990) in cognition, have claimed that understanding an organismic system (i.e., visual perceptual, cognitive, or any other assemblage) entails accounting for what that system does at various levels. Characteristically, their theoretical frameworks include levels that deal with (a) the goals of the system, or of a particular transformational process that the system performs, (b) the executive processes used to realise these goals, and (c) the biological mechanisms by which these processes are implemented. Anderson (1990), in his approach to human cognition, makes a point of stressing the level at which the goals of the system are specified. His view basically derives from two assumptions: (a) "The cognitive system operates at all times to optimize the adaptation of the behavior of the organism" (Anderson, 1990, p. 28), and (b) "Optimal behavior can be predicted by assuming that the system maximizes its goals while it minimizes its costs" (Anderson, 1990, p. 244). Accordingly, the level of goal specification "is about constraints on the behavior of the system in order for that behavior to be optimal" (Anderson, 1990, p. 22). Thus, for Anderson, cognitive systems are constrained by considerations of ecological adaptiveness.

Anderson (1990, p. 29) suggests that application of an ecological adaptive approach to cognition should involve, not only specifying the goals of the cognitive system, but also developing a “formal model of the environment to which the system is adapted”. According to Anderson, the main advantage of adopting such an approach is that, through the identification of specific goals and germane environmental characteristics, it provides guidance to generating hypotheses about the nature of executive processes and biological mechanisms that underlie cognitive acts. An undeniable consideration is that environmental events unfold through time. Hence, some recent attempts to understand cognitive, and other organismic systems within an ecological framework, have recognised the need to emphasise the role of temporal factors, or time generally, in interactions between organisms and their environments.

### 1.1.2 The importance of time

Cornerstone ecological approaches have implicated the temporal characteristics of both environmental and organismic systems as important determinants of behaviour. For instance, Gibson (1966, 1979) characterises visual perception as the extraction of invariants from a visual array that changes over time. Thus “Perception is an activity, not an instantaneous event” (Gibson, 1966, p. 143). Similarly, the *dynamical approach* to cognition deals with how humans and other animals process and represent information that changes over time. Advocates of this approach (e.g., Van Gelder & Port, 1995) claim that the temporal nature of interactions between individuals and their environments (i.e., their unfolding in real time) demands that attempts to model cognitive processes be sensitive to not only the serial order of processing operations, but also their relative timing. Within this paradigm, Jones (1976) and Jones and Boltz (1989) describe a theory of attention that “rests upon the assumptions that world structure is built within the constraints of three dimensions of space and one of time and that humans lawfully reflect world structure” (Jones, 1976, p. 327). According to their dynamic attending theory, a consequence of this tendency to share structural attributes is that qualitatively distinct temporal event structures afford different modes of attention.

Richelle and Lejeune (1980) apply some related principles in a more general examination of the role of time in animal behaviour. Basically, their research is framed by the question: “what environmental selective pressure could have been at work to account for timing behaviour…?” (Richelle & Lejeune, 1980, p. 6), and thus represents an attempt to understand ‘temporal adaptation’, through which organisms adjust to both the temporal structure of their environment, and to more arbitrary durations. The most notable quality shared by these various approaches to human and nonhuman behaviour is the assumption that organismic systems have evolved to produce optimal, and hence adaptive, temporally-based responses to temporally-based environmental events. Michon (1985) presents a neat characterisation of this view.

Michon (1985, p. 20) postulates that "Time is the conscious experiential product of the processes which allow the (human) organism to adaptively organize itself so that its behavior remains tuned to the sequential (order) relations in its environment". Therefore, "temporal relations contain information and both humans and animals use this information to guide their behavior" (Michon, 1985, p. 32). After Wohnam (1976), he argues that the process of extracting this information involves the organism forming an elaborate internal representation of these environmental temporal relations that can be subsequently used to guide behaviour. This behaviour will be optimal to the extent that the organism is able to function independently from its surrounding conditions. Michon (1985, p. 29) provides the following pithy articulation of his argument:

> "The process of gradual internalization of environmental variations in a form of 'internal representation' creates conditions that allow the optimization of the organism's functions. At the same time, however, it also creates a new problem. In order to remain in pace with the flow of events in the outer world, a very sharply tuned 'interface' with the environment is required. At some point in time, namely the point which we call *now* or *present*, there must be a close-to-perfect correlation between what is happening outside the individual and the representation thereof 'inside'. Any species that would be incapable of tuning its internal events to those in the outer world would stand as much chance in evolution as the proverbial soluble fish…".

The emergence of time as a mediating factor in interactions between individuals and their environments, implies that valuable insights into understanding musical interactions may be gained by developing models of their temporal aspects, that is, rhythmic behaviour, within an ecological framework. Unfortunately, this practice is traditionally quite rare: "little attempt has been made to coordinate the experience of time in music with theories of time perception of a more general sort" (Clarke & Krumhansl, 1990, p. 220). This apparent independence of time psychology and music psychology is perhaps a function of the former being more explicitly committed to ecological concerns. However, since some of the so-called ecological approaches to general temporal behaviour described above claim extensions into musical domains (e.g., Jones & Boltz, 1989; Michon, 1985), it will be necessary to assess the degree to which existing models of musical rhythmic behaviour address, either explicitly or implicitly, considerations of ecological adaptiveness.

# 1.2 Approaches to rhythm and meter

## 1.2.1 Descriptions of rhythm, meter, and their determinants

### 1.2.1.1 Rhythm

The term *rhythm* generally concerns the temporal patterning characteristic associated with a sequence of events. The attribute of this temporal patterning that most typically receives emphasis in definitions of rhythm is *orderliness*. For instance, after considering its etymological roots, Fraisse (1982, p. 150) suggests that "Rhythm is the ordered characteristic of succession". And *regularity*, in terms of the periodicity with which events occur, is usually implicated as the chief contributor to this orderliness. In fact, Clynes &

Walker (1982, p. 171) make the rather terse claim that “Rhythm means reiteration”. Along these lines, Bolton (1894, p. 146) notes that “There is a periodic recurrence of a certain phenomenon, sometimes accompanied by others, going on continuously in all that pertains to nature. Motion, whether in the broader field of the universe or upon the earth, is very generally periodic”. He goes on to cite examples ranging from “cosmic rhythms” (e.g., the lunar period) to “physiological rhythms” (e.g., heartbeat, respiration, and locomotion).

Appealing exclusively to the concepts of temporal order and regularity produces a definition of rhythm that is general enough to embrace an immense range of phenomena, as is evident in Bolton’s (1894) observations. Indeed, Parncutt (1994a, p. 452) points out that “The word rhythm may be used to describe any form of temporal periodicity observable in the physical universe, from molecular vibrations… right up to the ‘rhythm’ of expansions and contractions of the universe between hypothetical big bangs…”. The definition of rhythm needs to be refined in order to describe the ecological contexts in which musical rhythm exists. This entails distinguishing the physical and psychological conditions that support musical rhythm from those that support nonmusical rhythm. This distinction can be defined according to (a) the timescale along which event sequences occur, and (b) the manner in which an organism subjectively experiences grouping in the structure of the objective event sequences.

##### *1.2.1.1.1 Timescales*

Events based in both organisms and environments unfold along different timescales (Clynes, 1986; Gibson, 1979; Richelle & Lejeune, 1980), which overlap to some degree. Events such as seasonal change, continental drift, evolution of species, and even the developmental stages in the growth of an individual organism progress at the largest time scales, which can be called *macroscopic timescales*. At the other extreme, at what can be called *microscopic timescales*, physicists observe processes such as the movement of subatomic particles. Intermediate to the macroscopic and microscopic scales are what can be termed *mesoscopic timescales*. Much of the activity that progresses at mesoscopic time scales is attentional activity that is confined to what is known as the *psychological present*, although memory systems commonly allow these activities to extend into longer time periods. The psychological present, which has also been termed the *span of consciousness* (Wundt, 1874) and the *specious present* (James, 1890/1950), is defined by Parncutt (1994a, p. 450) as “a continuous time interval comprising all real time percepts and sensations simultaneously available to attention, perception, and cognitive processing”. Estimates of the duration of the psychological present vary considerably (see Parncutt, 1994a), but are typically in the order of 2 to 8 seconds (Fraisse, 1963).

The macroscopic, mesoscopic, and microscopic timescales all may be considered to have relevance to music cognition - stylistic evolution occurs at a macroscopic level, the perception of motivic and formal structure occurs at a mesoscopic level, and pitch and timbre perception takes place at a microscopic level. Nevertheless, it is mesoscopic timescales that are most germane to the study of musical rhythmic behaviour. This is consistent with Fraisse's (1982, p. 171) claim that musical rhythm "has a duration of from 2 to 5 sec". According to Fraisse (1982, p. 150) these limits are necessary to ensure that the listener is able to "directly perceive the order – that is to say, the succession…". In event sequences that exceed the limits of the psychological present, temporal order is not perceived directly. Rather, "ordering is reconstructed on the basis of experiences stored in memory" (Fraisse, 1978, p. 235) or some other process of "mental construction" (Fraisse, 1982, p. 150), such as imagination (Clynes, 1986).

#### *1.2.1.1.2 Rhythmic grouping*

Although it is perhaps necessary for a temporal event sequence to be specifiable within a mesoscopic timescale for it to be justifiably classified as musical rhythm, this condition is certainly not sufficient in itself. Many biologically-based temporal actions meet this criterion, for example, heartbeat, respiration, alpha brainwave activity, and motor timing mechanisms. Interestingly, links have been proposed between the rhythms of these physiological activities and both the origins of, and preferences for, musical rhythm (e.g., Clynes & Walker, 1982; Fraisse, 1982; Parncutt, 1987, Todd, 1994). Furthermore, some approaches focus upon the existence of structural commonalities between the rhythms of speech and music (e.g., Martin, 1972). However, despite these connections between musical and nonmusical rhythmic behaviour, most researchers seem to agree that musical rhythm patterns afford a unique style of perceptual organisation. Thus, it is commonly argued that the key attribute of musical rhythm is that it encourages the listener to abstract from temporal sequences periodic group boundaries that reflect regular time spans, defined by adjacent or nonadjacent events. As Parncutt (1994a, p. 453) puts it, "Periodic perceptual grouping appears to represent the most appropriate basis for a definition of musical rhythm. Periodic grouping is typical in music, but relatively unusual in speech…".

There appears to be consensus that, in order to experience musical rhythmic grouping, the listener must actively engage in perceptual and cognitive processes that involve organising the temporal event sequence as it unfolds in real time. As such, musical rhythmic grouping is a subjective experience, rather than purely an objective structural characteristic of temporal event sequences. Hence, psychological approaches to musical rhythm perception generally emphasise the role of the listener in determining pattern structure. For instance, the notion of subjective patterning is voiced strongly in Davies' (1978, p. 177) view of musical rhythm as "an order which the listener imposes upon sequences of events…". Further, Gabrielsson, (1993, p. 95) claims that musical rhythm, in fact, resides exclusively within the listener: "we adopt a working definition of musical or auditory rhythm as being 'a response to music or sound sequences of certain characteristics, comprising experiential as well as behavioral aspects'". Agmon's (1990) cognitive-scientific approach to musical rhythm, which distinguishes between *external realities*, such as physical (acoustic) duration, and *internal realities*, such as perceptual (auditory) duration and cognitive (symbolic) duration, represents a sophisticated music-theoretic treatment of this point.

#### *1.2.1.1.3 Defining musical rhythm*

Several issues emerge as important to any attempt at describing musical rhythmic behaviour, either in terms of theoretical definitions or formal psychological models. For such descriptions to be ecologically valid, they must, at minimum, address the interactive relationship between (a) physical factors associated with the time scale and objective structure of event sequences, and (b) psychological factors related to perceptual grouping mechanisms that contribute to the subjective experience of musical rhythm. In addition, evidence of a salient emotional component to rhythmic experience (Clynes, 1986; Clynes & Walker, 1982; Gabrielsson, 1993; Vos, 1973) demands that the aesthetic intentions of the agent responsible for creating a particular sequence should be considered (although this issue seems to be viewed as trivial for formal models of rhythm perception). It follows that a musical rhythm pattern can be defined as any auditory temporal sequence in which the time intervals between musical events have been manipulated by a creative agent (e.g., composer; performer; improviser) so as to encourage a listener to directly perceive aesthetically valuable groups. Hence, *musical rhythm perception* is activity that ultimately makes sense or nonsense of aesthetically valuable auditory temporal patterns through perceptual and cognitive grouping mechanisms. Abstract phenomena such as pulse, accent, and meter have been identified as indices of such grouping mechanisms.

#### 1.2.1.2 Pulse

Musical pulse, or beat, refers to the sensation of isochronous impulses[1] that are usually generated within an individual during the perception or production of musical rhythm patterns. The temporal interval between impulses is correlated with some periodicity, which Jones (1992, p. 93) calls a "referent time period", defined by a rhythm pattern's structure. Although this periodicity is typically implied by the relative temporal location of pattern elements, it does not necessarily have to be explicitly marked by pattern elements (Johnson-Laird, 1991; Parncutt, 1994a). Handel (1989, p. 391) observes that "Beats are often marked by the onset of individual sounds, but the sense of beats can occur even without physical events". This suggests that pulse is not derived exclusively through the bottom-up process of 'searching' through a pattern and extracting information about the periodicity with which events occur, but that individuals are also predisposed to more or less spontaneously supply a hypothetical pulse during rhythmic perception or production. Parncutt's (1987, p. 132) recommendation that "It is useful to imagine a pulse as a kind of template which is mapped against the pattern of events evoked by a rhythmic sequence", is consistent with this characterisation of pulse generation as a partially top-down process.

The experience of pulse sensation is typically considered to be confined to rates, or *tempos*, where the inter-impulse period is well within the limits of even the most conservative estimates of the psychological present. After conducting a thorough literature review, Parncutt (1994a) concludes that pulse sensations potentially exist in a rate region where their period is between 200 ms and 1800 ms. However, the "region of greatest pulse salience" is bounded by periodicity limits of 400 ms and 900 ms, with the most salient pulse sensations having a period of 600 ms (Parncutt, 1994a, p. 437). These apparent limits upon the periodicities that support pulse sensations provide clues about the identity of the underlying biological mechanisms. Although the issue is far from resolution, a wide variety of such mechanisms have been proposed. These include neural timing circuits incorporating the cerebellum (Ivry & Keele, 1989), auditory nerve responses (Todd, 1994), and endogenous oscillators (Klein & Jones, 1996; Large & Jones, 1999; Large & Kolen, 1994; McAuley, 1994; Treisman, Cook, Naish, MacCrone, 1994). It is noteworthy that these mechanisms have been implicated as playing a role in the temporal regulation of basic behaviours that are not necessarily music-related (e.g., motor synchronisation). In

[1] The term 'impulse' is used here to designate a single element within a series of pulsations, termed 'pulse'.

fact, Parncutt (1987, p. 129) postulates that "(t)he universality of pulse suggests that it has an extramusical origin".

Theories maintaining that motor activity underlies the experience of rhythm and pulse experience (see Radocy & Boyle, 1988 for a review) are consistent with this view. In this vein, Todd (1996, p. 189) has recently proposed that pulse sensation arises through the "imagination of a movement" that corresponds to activity in the association motor cortex. Indeed, there are several existing quantitative models of motor timing that address rhythmic behaviour (see Vorberg & Wing, 1996). Furthermore, Clynes (1977, 1983, 1985, 1986) has argued that pulse in music reflects the identity of the composer in subtle ways. To reveal the composer specific 'inner pulse', Clynes had highly accomplished musical performers 'conduct' their imagined rendition of various works by pressing with a finger on the pressure transducer of an instrument called the 'sentograph'. When the finger presses were analysed, it was found that their amplitude envelope differed systematically for the music of different composers. For example, the 'Mozart pulse' is "lighter and more buoyant in character" than the 'Beethoven pulse' (Clynes, 1986, p. 177).

Some researchers view pulse as the definitive correlate of rhythm. Parncutt (1994a, p. 453) proposes that "A musical rhythm is an acoustic sequence evoking a sensation of pulse", and Gabrielsson (1993, p. 96) argues that "to grab the pulse is basic to the experience of rhythm". Indeed, it is generally acknowledged that pulse, in its capacity as a "functional musical time unit" (Jones, 1987a, p. 624), serves as an elementary basis for rhythmic grouping. Accordingly, pattern elements that occur between pulsations may be grouped in relation to those that coincide with pulsations. Further cues to rhythmic grouping are provided by patterns of accentuation.

#### 1.2.1.3 Accent

Accent concerns the perceptual salience afforded by a point in time. In music, these time points are typically specified in relation to *time units* defined by a pulse period, or its regular subdivision. An individual time unit is said to be accented if it has been emphasised or made prominent, relative to its neighbouring units (Radocy & Boyle, 1988). This emphasis, and therefore the experience of accent, may be induced by various means. The factors that influence accentuation can be compiled into a taxonomic system comprising pitch-related, dynamic, and temporal factors.

*Pitch related factors* that have been recognised as influencing accentuation include (a) the extreme points (i.e., relatively high and low pitches) of contour changes (Cooper & Meyer, 1960; Creston, 1964; Jones, 1987a, 1993; Monahan & Carterette, 1985; Thomassen, 1982), (b) relatively large pitch intervals (Handel, 1989; Jones, 1987a, 1993), (c) the degree to which harmonic, or tonal, goals are either fulfilled or violated (Creston, 1964; Dawe, Platt, & Racine, 1995; Jones, 1987a, 1993; Smith & Cuddy, 1989), (d) melodic repetition (Creston, 1964; Steedman, 1977), and (e) embellishment involving melodic decoration (Benjamin, 1984; Creston, 1964). *Dynamic factors* that affect accentuation include (a) the intensity of a sound (Cooper & Meyer, 1960; Creston, 1964; Handel, 1989) and (b) changes in texture (Creston, 1964). Finally, *temporal factors* include (a) the duration of sounds (Cooper & Meyer, 1960; Creston, 1964; Handel, 1989; Jones, 1987a, 1993) and (b) the time interval between successive sound onsets (Palmer, 1989; Parncutt, 1994a; Povel & Okkerman, 1981).

The large number, and the diversity, of factors that contribute to the perceptual salience of a time unit have proven to be problematic in discussions of accent (Agmon, 1990; Cooper & Meyer, 1960). Not only are these factors typically found to affect accentuation to differing degrees (Berry, 1976; Dawe, Platt, & Racine, 1995; Palmer, 1989), but under some circumstances they may reinforce one another, whereas in others they may be in conflict (Handel, 1989). Further complications are due to the fact that some determinants of accent are the product of the interaction of different factors. For instance, Jones (1987a, 1993) describes "joint accent structures", in which accents are marked by "prominent attention-getting relational changes" in both pitch and duration (Jones, 1993, p. 76). In addition, articulation (i.e., the effect of method of production upon a sound's envelope) may be considered to involve the manipulation of both durational and dynamic factors (see Clarke, 1987b; Parncutt, 1994a; Sloboda, 1983).

Another potential source of confusion in discussions of accent is the distinction between situations when information about patterns of accentuation are provided in the physical sequence, and situations when the listener apparently imposes an accent structure in the absence of such information. Accordingly, Lerdahl and Jackendoff (1983) distinguish between *phenomenal accents* (which are determined by the acoustic properties of the signal) and *metric accents* (arising through the influence of cognitive organisational schemes). Likewise, Davies (1978) distinguishes between *objective accents* - those that result from the differentiation of sounds in terms of their physical characteristics (such as pitch, duration, and dynamics) - and *subjective accents* – those that are perceived in sequences of physically identical sounds. Examples of subjectively created accents include those that are produced by factors such as the time interval between successive sounds. Povel and Okkerman (1981, p. 570), after examining the effect of this factor using repetitive two-tone sequences in which the interval following the first and second tone was varied (see Figure 1.1), conclude that:

> "…the relative length of a silent interval following a tone in equitone [tones with the same frequency, spectral composition, intensity, and duration] sequences is an important determiner of a perceived accent on that tone. The longer the silent interval, the better the chance that tone will be perceived as bearing an accent. The effect is limited in two respects: (1) The shorter interval [i.e., the interval between the two tones] must be less than 250 ms. (2) There must be a minimal difference between the two intervals, which depends on the absolute length of the shorter interval."

Povel and Essens (1985) extend this principle in *accent rules* stating that perceptual emphasis is afforded by (a) sounds which are relatively isolated, (b) the second of a cluster of two sounds (if the interval between these sounds is less than 250 ms and a relatively long interval follows the second sound), and (c) the first and last of a cluster of three or more sounds.

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>       >   >   >       >       >
x------xx---xxxxx-------x------xx
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**Figure 1.1:** Accents in an equitone sequence. 'x' respresents a sound element with 150 ms duration, '-' is a 150 ms silent interval, and '>' signifies an interval produced accent.

Although time interval produced accents, unlike pitch-related or dynamic accents, can not be explained convincingly by appealing to 'attention-getting' properties (Jones, 1987a, 1993), they do permit some attractive alternative explanations. For example, Povel and Okkerman (1981), borrowing ideas from Massaro (1972), explain their observations by proposing that, when the processing of a sound stored in echoic memory is interrupted by the occurrence of another sound, the intensity of the first sound is underestimated. However, situations arise where the experience of accent defies explanation by appealing to such bottom-up mechanisms. Circumstances have been described where accents are perceived in sequences in which sounds are not only physically identical, but also where they occur isochronously. Bolton (1894) describes a phenomenon whereby accents are imposed upon the time units underlying such sequences, such that the constituent sounds are felt by the listener to be grouped by twos, threes, or fours, depending upon presentation rate (see Fraisse, 1982; Handel, 1989; Parncutt, 1994a). This so-called *subjective rhythmization* phenomenon reflects a tendency to group sounds, even if there is no basis for grouping inherent in the physical sequence. Thus, like some aspects of pulse sensation, subjective rhythmization exemplifies the action of top-down perceptual and cognitive processing. Moreover, it highlights links between the experiences of accentuation and rhythmic grouping (although in this case accents are perceived as a consequence of grouping, rather than vice versa).

Davies (1978, p. 197) points out that both objectively and subjectively created accents "serve as cues which the listener uses to form perceptual groupings". Thus, patterns of accentuation may convey rhythmic structure. Cooper and Meyer (1960, p. 8), propose that "the accented beat is the focal point, the nucleus of the rhythm, around which the unaccented beats are grouped and in relation to which they are heard". Indeed, the importance placed upon the process of grouping in musical rhythm perception has prompted some researchers to emphasise the role of accent in their definitions of rhythm. For instance, Vos (1977, p. 183) claims that "auditory rhythm perception occurs when a listener hears a series of sounds as consisting of sequential and similarly structured groups of accented and nonaccented sounds". Similarly, Cooper and Meyer (1960, p. 6) state that "Rhythm may be defined as the way in which one or more unaccented beats are grouped in relation to an accented one". The regularity with which accents occur along a sequence of pulses and the implications that this regularity holds for the grouping of pulses is crucial to the concept of meter.

#### 1.2.1.4 Meter

The concept of *musical meter* has featured in music theoretic descriptions of Western music from the sixteenth century onwards (Houle, 1987). These descriptions, as well as more psychologically-based descriptions of meter, typically refer to the simultaneous occurrence of two levels of pulsation. One of these levels corresponds to what are commonly known as *beats*, and the other relates to *measures*, or *bars*. The relationship between these pulsation levels is usually one in which bar-level pulsations occur at integer multiples of beat-level pulsations. Thus, a hierarchical structure obtains where beat-level pulsations are grouped into regular units by bar-level pulsations. Conventionally, beat-level pulsations that are grouped in twos are referred to as constituting a *duple meter*, beat-level pulses grouped in threes are said to establish a *triple meter*, beat-level pulses grouped in fours give rise to *quadruple meter*, and so on. In other words, meter can be conceptualised as a cognitive framework consisting of beat-level and bar-level pulsations that are hierarchically nested in some ratio such as 2:1 (duple meter), 3:1 (triple meter), or 4:1 (quadruple meter) (see Figure 1.2). According to Handel (1992, p. 498), meter is experienced as "the sense of a regular periodic sequence of subjectively stronger and weaker beats [pulses] that characterise music… The strength of any beat/element is determined by the number of levels at which the beat appears".

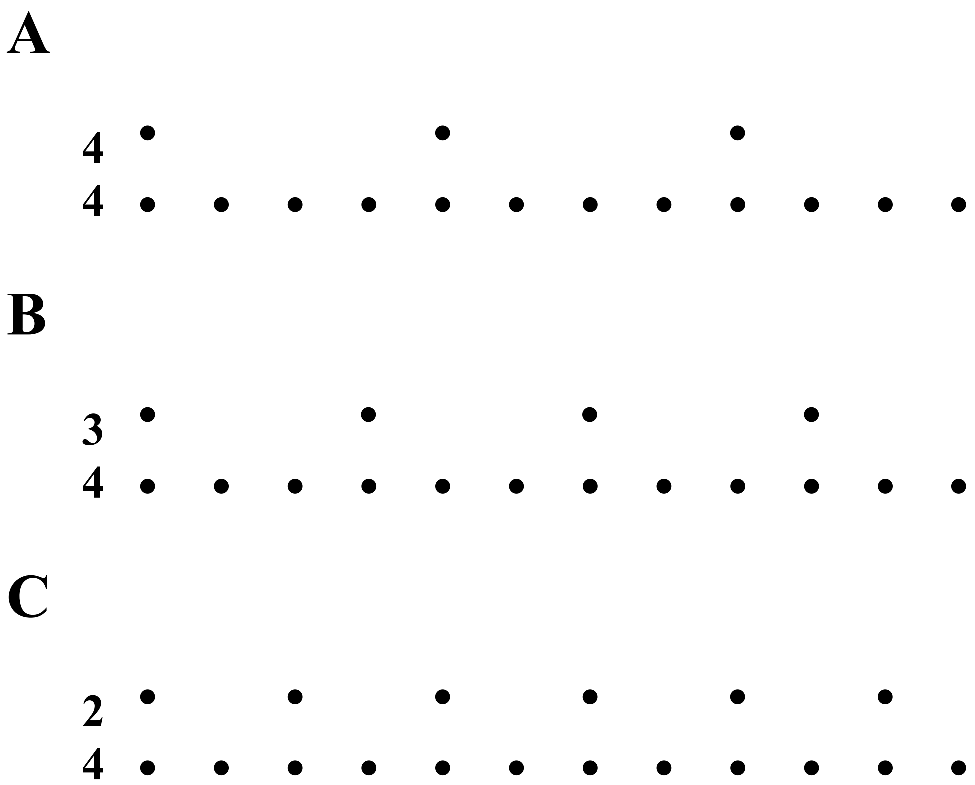



**Figure 1.2:** Graphic representation of beat- and bar-level pulsations defining *quadruple meter* (Panel A), *triple meter* (Panel B), and *duple meter* (Panel C). In each panel, the upper row of dots marks bar-level pulsations, and the lower row marks beat-level pulsations. Conventional musical 'time signatures' for describing the number of beat per bar are included before their related frameworks (e.g., $\frac{4}{4}$ indicates four beats per bar).

Despite its long history and common usage, the precise definition of the term 'meter' appears to be problematic. Different theories make different claims about *what* meter is (both cognitively and biologically) and *how* it is determined. Contention about the cognitive manifestation of metric frameworks relates primarily to their hierarchical nature. Although most theorists agree that meter *usually* consists of hierarchically related pulsations, they differ on issues such as the number of levels that make up metric frameworks, and whether these frameworks are *necessarily* hierarchic. Benjamin (1984, p.

371) finds it necessary to "think of meter as not necessarily, although normally, hierarchic and to speak of a single level of pulsation as a metric level…". However, many existing models of rhythm perception (e.g., Povel and Essens, 1985; Essens,1995) assume that meter consists of a two level hierarchy. Similarly, several approaches (e.g., Jones & Boltz, 1989; Palmer & Krumhansl, 1990; Yeston, 1976) argue that two levels are necessary to form a metric framework, but imply that more than two levels are possible under some circumstances. Further, with regard to biological mechanisms, numerous physiological processes have been implicated as mechanisms responsible for the experience of pulsations that comprise metric frameworks (see 1.2.1.2).

There is also considerable disagreement about the degree to which various properties of musical rhythm patterns influence the selection and generation of metric frameworks. Different approaches focus upon different properties, and their effects are rarely directly compared. Pattern properties that have been identified as important determinants of meter include: (a) the relative duration of pattern elements (e.g., Longuet-Higgins & Lee, 1982; Steedman, 1977); (b) the duration of time intervals between onsets of elements (e.g., Parncutt, 1994a; Povel & Essens, 1985); (c) frequency counts of note onsets at different positions throughout a pattern (Palmer & Krumhansl, 1990); (d) temporal invariants produced by ratio and additive time transformations inherent in an event's structure (Jones, 1976; Jones & Boltz, 1989); (e) melodic repetition (Steedman, 1977); and (f) harmonic structure (Dawe et al., 1995). These properties are generally assumed to affect the experience of meter through their influence upon accentuation.

It is commonly held that accents serve as cues, or "perceptual input" (Lerdahl & Jackendoff, 1983, p. 17), to meter. However, there are also problems in conceptualisations of the relationship between meter and accent. In response to a prevailing tendency to refer to accent in descriptions of metric hierarchies (e.g., Berry, 1976; Cooper & Meyer, 1960; Monahan & Carterette, 1985; Palmer & Krumhansl, 1990; Radocy & Boyle, 1988), Agmon (1990, p. 303) claims that "accent… is irrelevant to *what* meter is; accent is relevant only to *how* meter is perceived…".[2] His argument hinges upon appreciating a distinction between the concepts of pulsation strength (related to the number of hierarchical levels along which pulsations occur) and accent. In Agmon's (1990) view, accents encourage a listener to invoke a particular metric framework - wherein pulsation strength varies at different metric locations - but are not themselves features of this framework. He

[2] One could, in fact, argue that meter is not actually *perceived*, but rather is *generated* within an individual either in reponse to an external pattern of accents or spontaneously (see Chapter 3).

acknowledges that this notion is captured by Lerdahl and Jackendoff's (1983) distinction between phenomenal and metrical accents, buts finds that their "liberal usage of the term 'accent'… is potentially confusing and is best avoided" (Agmon, 1990, p. 303).

In contrast to the business of describing metric frameworks, the specification of the *role* of meter is rarely considered to be controversial. Most approaches to rhythm perception seem to agree that meter's primary function is rhythmic organisation. Consequently, meter is incorporated into many definitions of musical rhythm. For example, Jones and Boltz (1989, p. 467) state that "Rhythm refers to patterned time changes within a metric frame". This is consistent with Handel's (1992, p. 498) conception of meter as a grid, or "time-based lattice that serves to create the rhythmic organization", and Parncutt's (1994b, p. 146) description of meter as a "cognitive temporal frame of reference within which to organise temporal events".

It is generally accepted that meter fulfils its function as rhythmic organiser by providing a basis for grouping the sounds comprising a rhythm pattern in relation to the beat- and bar-level pulsations that define metric hierarchies. Accordingly, Jones (1987b, p. 157) observes that "Traditionally, meter is considered the basis for temporal grouping". Furthermore, it has been argued that metric frameworks serve as a basis for the anticipation, or expectation of events in various musical dimensions (e.g., tonal, harmonic, and intensity), and thereby guide a listener towards explicit grouping cues (Jones, 1982, 1990; Jones & Boltz, 1989; Palmer & Krumhansl, 1990).

It is noteworthy that some additional, albeit related, functions have been ascribed to meter. Benjamin (1984) considers meter's primary aesthetic function to be the organisation of time points into equivalence classes such as the first beat of the bar, the second beat, and so on. According to Benjamin (1984), this allows the listener to structure time-points in a way that is analogous to the perception of equivalent pitch structures in the concept of chroma (e.g., tones with fundamental frequency components of 220, 440, and 880 Hz are all called 'the note A' in the Western tonal system, but are said to be in different 'octaves', or registers). Another function of meter that Benjamin (1984) identifies is performance related:

> "It seems clear that in the context of Western music – a context, musically, of constant polyphonic opposition among, and high complexity within, the individual parts; historically, of quick stylistic evolution; and sociologically, of communication among superinitiates (composers), initiates (performers), and

> acolytes (listeners) – meter is vital to stability of reproduction and plays an essential enabling role in the doctrine of fidelity to the artefact" (p. 372).

Thus, he alludes to meter's role in providing a common frame of reference that assists the coordination of musicians performing, and audiences listening to, polyphonic music (where distinctive instrumental or vocal parts occur simultaneously). Shaffer (1985, p. 237) provides empirical evidence that in musical ensembles "players coordinate their representations of meter".

The related functions of meter as (a) a basis for rhythmic grouping, (b) a means of structuring time-points, and (c) a way of measuring time that can be shared between performers and listeners, suggests that it acts as a cognitive temporal frame of reference which allows the relationship between musical events to be appreciated, as well as to be produced, perceived, remembered, recalled, and reproduced in a manner that is both efficient and accurate. In short, the formation of metric frameworks facilitates the efficient processing and representation of rhythm patterns.

### 1.2.2 Describing the musical rhythmic environment

The interpretation of musical rhythm is driven by the goal to organise auditory temporal event sequences into meaningful regular perceptual groups. This grouping allows information about temporal relationships between musical events to be accurately stored in, and retrieved from, memory. Any perceptual, motor, and cognitive mechanisms that may be in place to realise this goal, such as those responsible for formation of metric frameworks, are constrained in terms of their function in recognising, abstracting, and utilising information about temporal regularity contained in event sequences. In order to understand how these mechanisms perform these operations, and the problems that they face in doing so, it is necessary to specify the types of temporal structures that are encountered in the musical rhythmic environment. Thus, in line with ideas originally proposed by Brunswick (1949, 1956) and Gibson (1966), a thorough description of the stimulus environment will inform the process of understanding the workings of the perceptual and cognitive systems that deal with this environment. Even if this description lacks the level of formalism recommended by Anderson (1990), it should enable rigorous treatment of rhythmic behaviour.

#### 1.2.2.1 Rhythmic complexity and metricality

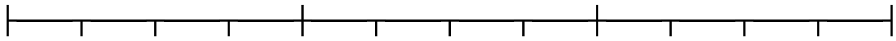
Auditory temporal sequences that occur in musical environments vary in rhythmic complexity. Many approaches to rhythm perception (e.g., Gabrielsson, 1993; Jones & Boltz, 1989; Povel & Essens, 1985) have found it useful to measure rhythmic complexity in terms of how well a pattern's structure maps onto a hypothetical metric framework. Likewise, in the current approach, rhythmic complexity is loosely defined according to whether a pattern induces a metric framework, and if so, how well it fits that framework. This definition, which introduces the concept of *metricality* as an index of rhythmic complexity, suggests a distinction between metrical and nonmetrical patterns. Note that the term 'metricality' will be used to refer to patterns that do not inspire metric frameworks (and are therefore lower in metricality), as well as those that do.

Temporal sequences that encourage the generation of metric frameworks to guide their interpretation are termed *metrical patterns*. Conversely, *nonmetrical patterns* do not encourage the generation of metric frameworks. The distinction between metrical and nonmetrical patterns derives from their fundamentally different types of temporal structures (Essens, 1995; Essens & Povel, 1985). In metrical patterns, the placement of pattern elements, and the distribution of accents (i.e., perceptually salient temporal locations) associated with these elements, imply regular underlying time periods. These pattern elements and accents therefore have the potential to mark the beat- and bar-level pulsations that constitute metric frameworks. On the other hand, nonmetrical patterns are not characterised by consistently regular element placement or accent distribution, and hence do not imply regular time periods. Hence, it has been argued that nonmetrical patterns are not, strictly speaking, 'rhythmic' (Gabrielsson, 1993; Parncutt, 1994a). Nevertheless, such patterns do feature in much contemporary music, and can be organised into coherent compositional structures according to principles that do not rely upon meter (Clarke, 1987).

Examples of metrical (quadruple and triple) and nonmetrical patterns are shown in Figure 1.3 (Panels A, B, and C, respectively). These examples are also presented on Tracks 1, 2, and 3 of the Compact Disc accompanying this dissertation. Note that pattern elements (x) occur periodically only in metrical patterns, where periodicities for quadruple and triple patterns correspond to their respective bar-level metric pulsations. Also note the relatively long silent intervals following elements that coincide with bar-level pulsations in Panels A and B. Povel and Essens' (1985) description of the conditions that give rise to the experience of accent suggests that the time points associated with these elements should be perceived to bear accents. Therefore, the patterns in Panels A and B should contain periodic accents that correspond to quadruple and triple bar-level pulsations, respectively. Although accents should also be experienced with the nonmetrical pattern in Panel C, the pattern's structure does not imply periodic accent placement.

**A**

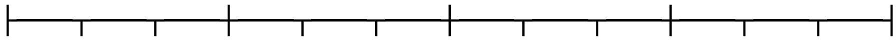
***Quadruple pattern***



```
x-----------x---x--------------xx-------x---x-x-x
```

**B**

***Triple pattern***



```
x----------xx-------x--xx-----------x---------x-x
```

**C**

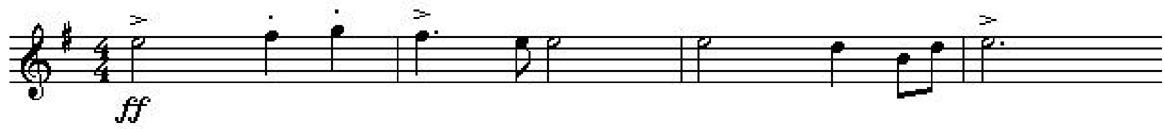
***Nonmetrical pattern***

```
x---------x---x----------x-x-----------x----x--xx
```

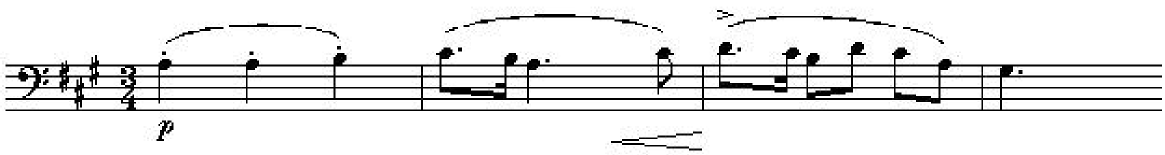
**Figure 1.3:** Rhythm patterns from the following categories: quadruple (Panel A); triple (Panel B); nonmetrical (Panel C). Grids representing various metric frameworks (or only beat-level pulsations in the case of the integrant patterns in Panel C) have been included to allow pattern structure to be gauged.

Some real examples of quadruple, triple and nonmetrical patterns are shown in Figure 1.4, Panels A, B, and C, respectively. Panel A shows an excerpt from the first movement of Dvorák's *Symphony No. 9* (see Track 4 on CD). The excerpt in Panel B is a melody from the second movement of Schubert's *Sonata in B flat*, D. 960 (see Track 5). Panel C shows the opening of Stockhausen's *Klavierstück VI* (reproduced from Stockhausen, 1965) (see Track 6). Note the graphical notation used by Stockhausen to compensate for the absence of metric structure in this piece. The strip of lines above the conventional notation indicates ongoing 'tempo' (tempo increases as the thick line moves higher on the grid). Indeed, developing conventions for the notation of nonmetrical music has proven to be a difficult issue, and individual composers generally invent unique solutions that suit their immediate purpose. Note that not all nonmetrical music is as ‘busy’ and ‘angular’ as the example in Figure 1.4, Panel C: Gregorian chant is also nonmetrical (see Track 7).

**A**




**B**




**C**

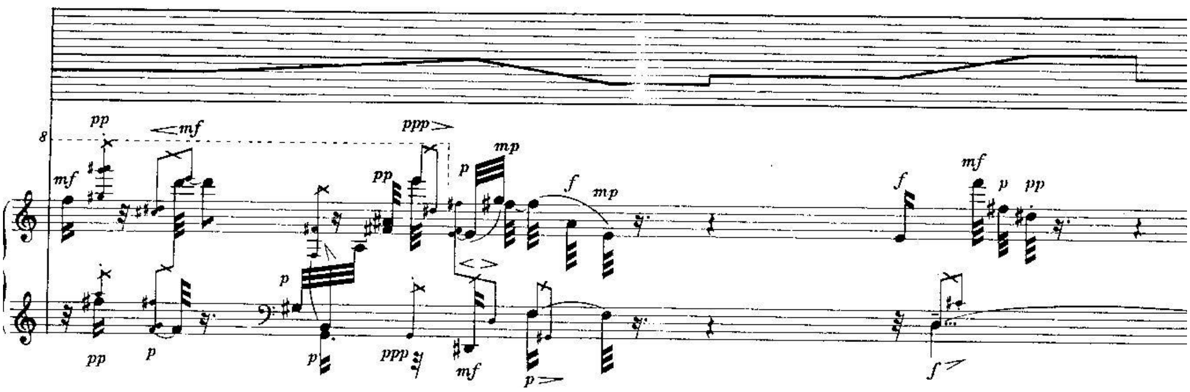


**Figure 1.4:** Quadruple (Panel A), triple (Panel B), and nonmetrical (Panel C) patterns from the corpus of Western music.

Due to their inherent recursiveness, metrical patterns are less complex than nonmetrical patterns (Jones & Boltz, 1989; Povel & Essens, 1985; Pressing, 1997). However, metrical patterns themselves may vary in complexity (Jones & Boltz, 1989; Povel, 1984, 1985). That is, some metrical patterns are more regular than others. Complexity increases in metrical patterns with decreasing coincidence between pattern elements and accents, on the one hand, and the beat-level and bar-level pulsations of a hypothetical metric framework, on the other. This can occur when a pattern is interpreted according to a meter other than its *meter of best fit*. Indeed, the task of selecting the best fitting meter is fundamental in rhythm perception: “Rhythmic organization… is fitting the meter grid to the note sequence. One would start with the grid of strong and weak beats and ‘slide’ the grid along the passage so that the strong beats fall on different notes as the grid moves. The problem then is to select the best meter for the note sequence” (Handel, 1992, p. 498). This description, albeit somewhat metaphorical, implies that although a given pattern may have the potential to be interpreted according to several different metric frameworks, an optimal metrical interpretation exists in which complexity is minimised (Povel, 1984; Povel & Essens, 1985). Behavioural data support this conception of the relationship between rhythmic complexity and metricality. Metrical patterns are typically found to be recognised and reproduced more accurately than nonmetrical patterns, and these behaviours are more accurate when metrical patterns fit a given metric framework well (e.g., Bharucha & Pryor, 1986; Essens, 1995; Essens & Povel, 1985; Franks & Canic, 1991; Handel, 1973; Handel, 1992; Jones & Yee, 1997; Povel, 1981; Povel & Essens, 1985; Sturges & Martin, 1974).

The issue of rhythmic complexity is complicated by the fact that perceptual and cognitive systems dealing with musical rhythm perception are required to manage different types of deviations from regularity in the sequences that they encounter. Music Theory has classified the numerous forms of temporal irregularity, and other complexities related to temporal structure, which characterise real-life musical contexts. These include rhythmic features such as syncopation, so-called complex meters, meter changes, polymeter, expressive timing, polyrhythm, and elaborate multipart rhythmic textures. It is widely acknowledged that such structural complexities fulfil important aesthetic functions (Arom, 1991; Cooper & Meyer, 1960; Clarke, 1987b; Gabrielsson, 1993; Jones & Boltz, 1989; Meyer, 1956; Povel, 1985; Pressing, 1983; Seashore, 1938/1967). Further, the pervasiveness of these phenomena suggest that they are definitive structural aspects of musical rhythmic environments, and, as such, need to be fully accounted for by models of musical rhythmic behaviour.

#### 1.2.2.2 Syncopation, hemiola, mixed meters, and complex meters

Syncopation refers to the violation of an established metric framework by the occurrence of an accent at a weak metric location, followed immediately by the de-emphasis of a strong metric location. More specifically, syncopation is conventionally said to result from two contiguous events: (a) when a sound onset coincides with either a weak metric pulsation (e.g., where an impulse is present at only the beat-level), or with no pulsation at all (e.g., at a subdivision of the beat-level unit), and (b) when the next strong metric pulsation (e.g., a bar-level impulse) that follows this sound onset is not itself marked by a sound onset (i.e., the previous sound is either terminated or sustained) (Cooper & Meyer, 1960; Longuet-Higgins & Lee, 1984). An example of syncopation is given in Figure 1.5 and Track 8.

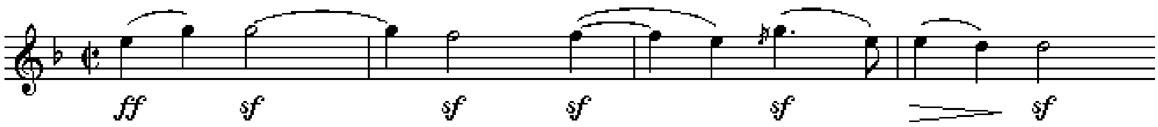



**Figure 1.5:** Syncopation in Smetana's overture to his opera *The Bartered Bride*. Syncopation occurs in this excerpt when the second and third sforzandi (marked '*sf*') lead to the accentuation of off-beats.

Johnson-Laird (1991, pp. 94-95) provides a more experiential description: "A syncopation… is the occurrence of a relatively long note at an unexpected place – as though it starts in anticipation of its proper place in metrical structure". He observes that the degree, or strength, of syncopation increases as the onset of the 'early' note approaches its expected location. However, degree of syncopation is not solely a function of the discrepancy between a sound's expected and actual location. Lerdahl and Jackendoff (1983, pp. 17-18) note that "Once a clear metrical pattern has been established, the listener renounces it only in the face of strongly contradicting evidence. Syncopation takes place where cues are strongly contradictory yet not strong enough, or regular enough, to override the inferred pattern". This implies that degree of syncopation is influenced by the persistence of the new set of temporal relations. If these new relations are sufficiently enduring, the listener may detect regularity in their structure. This regularity may then be used as the basis for adopting a new metric framework, and consequently the pattern is no longer syncopated. Parncutt (1994a, p. 451) mentions a threshold at which syncopations are perceived as changes in meter: "…pulse sensations and perceived meter are established quite quickly and are subsequently quite resilient in the face of potentially disruptive syncopations. Only when the degree or strength of syncopations passes a certain threshold will the perceived meter change". This *metric violation threshold* has been discussed by a number of researchers (e.g., Benjamin, 1984; Lee, 1991; Lerdahl & Jackendoff, 1982; Windsor, 1993). However, the parameters influencing its liminal value have not been quantitatively expressed. Indeed, it is likely that they are highly context dependent and variable.

The rhythmic device known as *hemiola*, which emerged during the fifteenth century, exploits the uncertain limits of the metric violation threshold. Monahan and Carterette

(1985, p. 5) describe hemiola as “the simultaneous bipartite and tripartite division of the same period by two sources of accenting”. Hemiola typically occurs when a section spanning two bar-units within an established triple meter context (i.e., a total of six beats) is accented such that it suggests a duple meter (i.e., an accent occurs every two beats). This practice of systematically violating a listener’s metric-based expectancies is intended to evoke aesthetically pleasant feelings of surprise. An indication of the popularity of hemiola is provided by its extensive use in the ‘Viennese waltz’ genre. In this style of dance music, sections spanning two bar-units occasionally occur, in which the melodic line produces accents that coincide with the first and third beats of the first bar unit, and with the second beat of the second bar-unit, thus suggesting a duple meter that conflicts with the triple meter implied by the underlying ‘Oom-pah-pah’ accompaniment. Hemiola also features prominently in the music of Brahms (see Figure 1.6 & Track 9). Yeston (1976) provides numerous further examples of the use of hemiola in Western music.

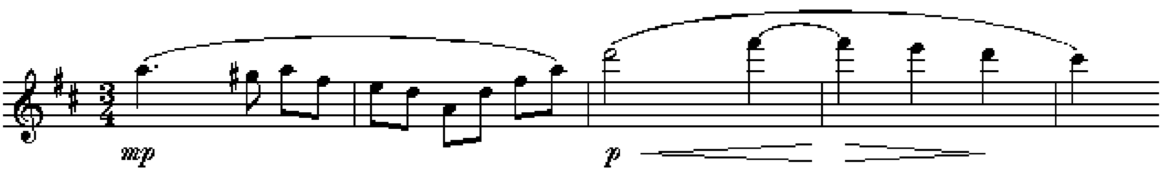



**Figure 1.6:** Hemiola in the first movement of Brahm’s *Symphony No. 2*. The hemiola occurs in the third and fourth bars of this excerpt.

Exceeding the metric violation threshold necessitates the formation of a new metric framework. Perhaps due to the aesthetically appealing turbulence of this process, some music is characterised by pattern structures that suggest frequent meter changes. London (1995) uses the term *mixed meters* to refer to the frameworks underlying patterns that involve such meter changes. Music that is said to be in mixed meters is, theoretically, often interpreted best according to frameworks where the duration of both beat and bar units varies from bar-unit to bar-unit (see Figure 1.7 and Track 10). These structures are thus nonhierarchical and nonrecursive, since the relationship between beat and bar level pulsations can not be described by a ratio that is held constant throughout the entire pattern.

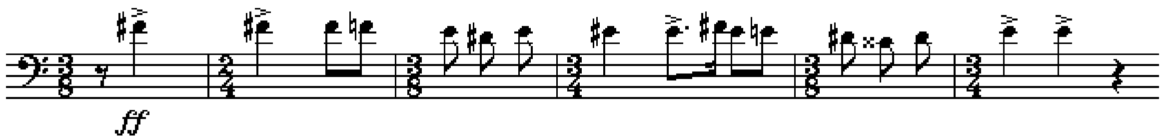



**Figure 1.7:** Mixed meter in the March from *The Soldier’s Tale* by Stravinsky.

Another irregular rhythmic device that has enjoyed popularity in Western music is the use of *complex meters*. In complex meters, either the beat-level pulsations *or* the bar-level pulsations of the metric framework are nonisochronous (London, 1995). London (1995, p. 71) points out that complex meters are hierarchical (since they "exhibit a clear organisation of nested structural levels"), although they are not recursive. Therefore, specifying the basic period of complex meters requires extra levels – either a hypermeasure level that groups the bar-unit and/or a level that subdivides the beat unit. The hypermeasure level can be used to compensate for the irregularity of nonisochronous bar-level pulsations by grouping them into equal durational units. Similarly, the subdivision level can be introduced as a kind of 'lowest common denominator', which subdivides unequal beat units into shorter equal durational units, and thus serves as a baseline for maintaining irregular beat-level pulsations. An example of complex meter is given in Figure 1.8 and Track 11. In this excerpt from Dave Brubeck's *Unsquare Dance*, the fast tempo encourages uneven grouping of the beat unit into groups of 2 + 2 + 3 beats (each group is initiated by a note in the bass line).

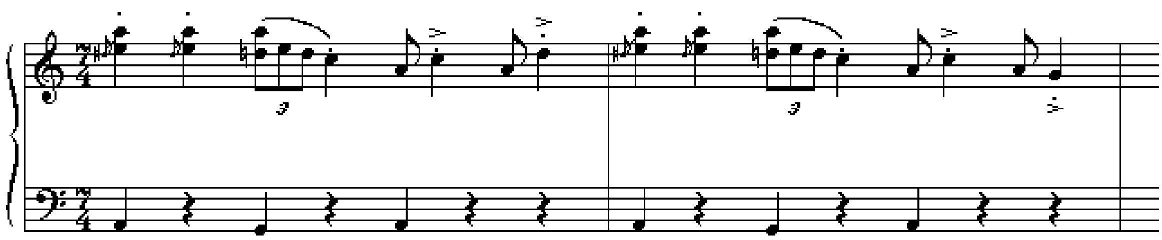


**Figure 1.8:** Complex meter in Brubeck's *Unsquare Dance*.

#### 1.2.2.3 Expressive timing and categorical rhythm perception

Musical performances in which the temporal relationships between sound events are realised with absolutely strict accuracy throughout the piece are rarely valued as ideal. Such interpretations are typically described as mechanical and boring (Gabrielsson, 1993). Instead, some departure from mechanical regularity is generally considered to be desirable. *Expressive timing* involves the introduction of such deviation into a performance. Clarke's (1989) finding that, under some circumstances, listeners are able to detect deviations that are only 20 ms in magnitude, may indicate that expressive timing can be effective even if it is quite subtle. Nevertheless, expressive deviations are often more pronounced, involving changes in tempo that are either gradual, such as accelerandi (getting faster) and deccelerandi (getting slower), or sudden, as in fermati (pauses) (Benjamin, 1984). Jones and Yee (1993) point out that, technically, any of these types of deviation render the performed patterns nonmetrical. However, it has been noted that expressive timing deviations are carried out in a systematic fashion (Bengtsson & Gabrielsson, 1983; Clarke, 1985, 1987b; Repp, 1992a, 1998b, 1999a; Todd, 1985). Clarke (1987b, p. 224) observes that "performers make use of variations in event timing in a controlled and reproducible manner". For instance, it is has been shown that tempo usually slows in the vicinity of events that are important in the definition of metric structure, for example, at the end of musical phrases (Penel & Drake, 1998; Repp, 1992a; Shaffer, 1984; Sloboda, 1983).

The systematic nature of expressive timing variations has been taken to indicate that they act as cues to properties of musical structure, such as meter, and thereby function as a means by which performers convey a particular interpretation of a piece to an audience (Clarke, 1988; Gabrielsson, 1999; Penel & Drake, 1998). The apparent paradox that deviations from temporal regularity can communicate regular metric structures evaporates when the contribution of these timing variations to the accentuation of structurally important time units is considered. It is often argued that the lengthening of important events produces duration-based accents (Clarke, 1988; Parncutt, 1994a), which, as mentioned earlier (section 1.2.1.4), signal strong metric locations. It appears as if the ability of listeners to abstract metric frameworks, in spite of expressive timing deviations, is due to the *categorical* nature of rhythm perception (Clarke, 1987a, 1987b; Schulze, 1989; Sloboda, 1985a).

Clarke (1987a, p. 22) has highlighted the ecological adaptive value of categorical perception generally: "Categorical perception functions so as to separate essential structural units or events from nonstructural information: in other words it separates the invariants of a perceptual context from the uncontrolled variations, or perceptual 'noise', that inevitably accompany them". In the case of musical performance, this 'noise' includes expressive timing.[3]

In rhythmic behaviour, categorical perception involves the assignment of events in a sequence to discrete temporal categories that correspond to time units usually specified according to a metric framework (see Windsor, 1993). Thus, it recruits a quantisation process (Desain, 1992; Desain & Honing, 1989). The perception of temporal location is biased by category boundaries, with ambiguity increasing as events approach these boundaries. However, the flexibility of category boundaries allows persistent ambiguities

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[3] The negative connotations of the term 'noise' are unfortunate in this context as expressive timing is the lifeblood of musical performance.

to be resolved. Clarke (1987b, p. 221) proposes that "the category boundaries are related to musical context, moving so as to facilitate metrically conformant interpretations of ambiguous rhythmic groups".

In a detailed series of studies, Repp (1992b, 1998a, 1998d, 1999a, 1999b) has found that the detectability of timing deviations varies as a function of location within the melodic-rhythmic grouping structure of the music. In particular, "the lengthening of a tone inter-onset interval (IOI) – an IOI increment, perceived as a hesitation – is usually more difficult to detect at the end of a group than at its beginning or centre" (Repp, 1999b, p. 188). Perhaps category boundaries are relaxed towards the end of melodic rhythmic groups due to the listener's expectations (see Repp, 1998c).

#### 1.2.2.4 Polyrhythm, polymeter, and auditory streaming

Polyrhythm results from the concurrent presentation of two or more sequences that suggest mutually incompatible pulses. These pulses are incompatible in the sense that they divide the same overall time period (the bar-unit) into numbers of temporal (beat-) units that combine to form inharmonic ratios such as 2:3, 3:4, 4:5, 3:4:5, etc (where the ratios reflect the relationship between the beat-level pulsations associated with separate sequences). Consequently, the temporal relationship between the sequences that comprise polyrhythmic patterns has been described as conflicting and dissonant (Handel & Lawson, 1983; Yeston, 1976).

Polyrhythm is a prevalent, if not definitive, characteristic of African music (Arom, 1991; Chernoff, 1979; A. Jones, 1959; Pressing, 1983). The rhythmic textural fabric of African drum music typically consists of conflicting patterns that mesh together in ways that promote ambiguous pattern percepts (see Track 12), and hence sustain a listener's interest and participation throughout a piece (Chernoff, 1979). It is common for polyrhythmic figures to be used as ostinati in African music, wherein ostinato is "the regular and uninterupted repetition of a rhythmic or melodic-rhythmic figure, with an unvarying periodicity underlying it" (Arom, 1991, p. 40).

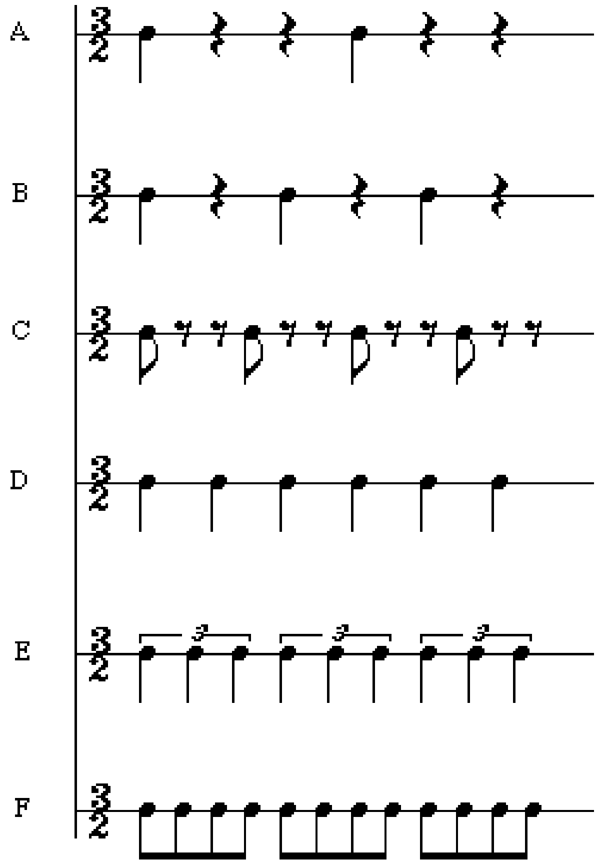


**Figure 1.9:** Polyrhythms from *Short Ride in a Fast Machine* by John Adams. This excerpt contains several different polyrhythmic structures that run concurrently. Three of these occur at the level of the bar unit - 2:3 (Parts A & B), 3:4 (B & C), 4:9 (C & E) - one occurs at the level of the half-bar unit - 2:3 (C & D) - and two at the level of the beat unit - 2:3 (D & E) and 3: 4 (E & F).

In Western music, polyrhythm is conventionally used in a more sporadic fashion. Polyrhythms usually punctuate structures that are predominantly regular, rather than providing a basis for entire compositions. However, there are exceptions to this tendency – for example in some sixteenth and twentieth century music – where, as in African music, rhythmically dissonant structures are prolonged (see Figure 1.9 & Track 13).

Such enduring dissonant structures are often said to be polymetric. Although the terms polyrhythm and polymeter are sometimes used interchangeably, it may be useful to reserve the term polymeter for describing large scale structures that result from the simultaneous presentation of extended sequences that best fit different metric frameworks, usually by different instruments, or groups of instruments. The essential difference (apart from differences in scale) between polyrhythm and polymeter is that the bar-level pulsations associated with each separate sequence coincide in polrhythmic structures, but not in polymetric structures. Notable examples of polymeter appear in the music of Béla Bartók and Charles Ives. For instance, in sections of Bartok's *3rd String Quartet*, separate instrumental parts play concurrently in different meters (see Figure 1.10 & Track 14, reproduced from Bartók, 1939).


**Figure 1.10:** Excerpt from the 'Seconda parte' of Bartók's *3rd String Quartet*. All parts start the excerpt in duple meter, but the viola (third from top) goes into triple meter at the second bar.

Most experimental studies that investigate the perception and production of dissonant rhythmic patterns are concerned with polyrhythmic, rather than polymetric, structures (e.g., Beauvillain & Fraisse, 1984; Deutsch, 1983; Handel & Lawson, 1983; Handel & Oshinsky, 1981; Jones, Jagacinski, Yee, Floyd, & Klapp, 1995; Klapp, Hill, Tyler, Martin, Jagacinski, & Jones, 1985; Pressing, Summers, & Magill, 1996; Summers, Rosenbaum, Burns, & Ford, 1993). Such studies distinguish between the conditions that encourage the perception of polyrhythmic patterns as integrated wholes, versus those that lead to the perception of separate, albeit simultaneous, sequences.

Conceiving a polyrhythmic pattern in terms of its integrated, or global, structure is often recommended as a strategy to assist performers who are required to produce such patterns, as in the case of a percussionist or pianist generating a different sequence with each hand (Pressing et al, 1996; Smyth, Morris, Levy, & Ellis, 1987). Deutsch (1983, p. 331) describes this type of global learning strategy, whereby "the performer generally learns first to produce the integrated pattern, and then to associate each component of the pattern with the appropriate hand, so that the two isochronous sequences finally emerge in parallel". A schematic diagram of this process is given in Figure 1.11. However, it has typically found that one sequence, or a subset of such sequences, dominates perception. This phenomenon has been discussed in terms of figure-ground relations. More specifically, it has been argued that, under some circumstances, one or more sequences may be perceived as a 'figure' that is superimposed upon a metric 'ground' consisting of the remaining sequence/s (Handel, 1984; Pressing et al, 1996).

## 3 x 4 Polyrhythm

| | |
|---|---|
| 3-stream (left hand) | x - - - x - - - x - - - |
| 4-stream (right hand) | o - - o - - o - - o - - |

**Step 1:**

| | |
|---|---|
| Integrate the 3- and 4-stream | v - - v v - v - v v - - |

**Step 2:**

Assign appropriate hand to elements in the integrated pattern

```
R       R       R
v - - v v - v - v v - -
L     L     L     L
```

(R = right; L = left)

**Figure 1.11:** The global learning strategy in 3 x 4 polyrhythmic performance.

Various factors have been found to affect whether polyrhythmic sequences are perceived as integrated or separated, and, if the latter is the case, which sequence/s function as ground, and which function as figure. The inter-element intervals in each sequence, which are largely a matter of presentation rate, have been found to be particularly influential (Handel & Oshinsky, 1981). Parncutt (1994a) relates this to the existence region of pulse salience, arguing that listeners use as a frame of reference the sequence, or combination of sequences, that evokes the most salient pulse sensation. Other influential factors include (a) the pitch range of each sequence, (b) the ratio relationship between the inter-element intervals in each sequence, and (c) duration and intensity differences between elements in the sequences (Handel, 1984; Handel, 1989). These factors affect the perception of polyrhythmic patterns in a manner that is reminiscent of their role in the *auditory streaming phenomenon*.

In traditional auditory streaming demonstrations (Bregman & Campbell, 1971; see Bregman, 1990; van Noorden, 1975), an isochronous sequence of alternating high- and low-pitch tones is perceived by listeners to segregate into a sequence of high tones and a sequence of low tones. The streaming effect is often relied upon in virtuosic solo instrumental music to create the impression of two instruments playing in an interleaved fashion (see Figure 1.12 & Track 15). As in the perception of polyrhythms, auditory streaming is affected by factors relating to presentation rate and the pitch distance that separates high and low tones. Streaming is most likely to occur when there are large pitch differences between the high and low tones, and at fast presentation rates. In addition, rhythmic structural factors have been found to affect the tendency for sequences to stream. In a series of experiments using anisochronous sequences, Jones, Kidd, and Wetzel (1981) demonstrated that streaming is influenced by the temporal relationships between tones within the high and low sequences, and the degree to which the temporal structures of these sequences are independent (also see Handel, Weaver, & Lawson, 1983).

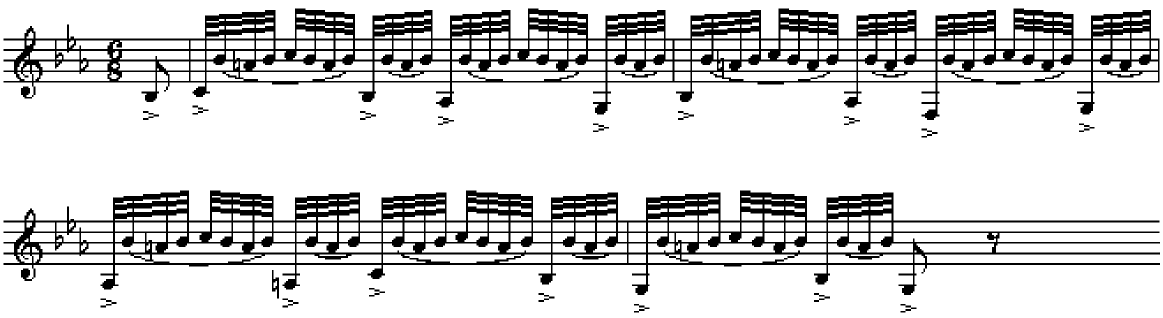

**Figure 1.12:** Arban's final variation on *The Carnival of Venice*. Streaming can be heard in the performance of this excerpt on Track 13 (featuring Wynton Marsalis on trumpet). The accented low notes can be heard as one stream, and the slurred higher notes as the other.

#### 1.2.2.5 Multipart rhythmic textures

Multipart rhythmic textures occur when different instrumental or musical parts articulate different rhythm patterns concurrently. These contrast with singlepart rhythmic textures, in which either there is only one instrumental or vocal part, or there is more than one part, but all parts articulate the same rhythm. In the excerpt from the fugue by Bach in Figure 1.13 and Track 16, the texture is singlepart until the entry of the higher part produces a multipart texture.

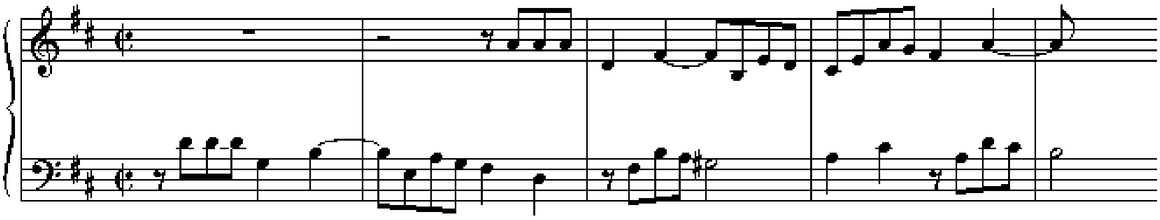

**Figure 1.13:** The opening of J.S. Bach's 'Fuga 5' from *Das Wohltemperierte Klavier II.*

Multipart rhythmic textures are very common – they have dominated Western popular and art music for over 700 years (i.e., since the blossoming of polyphony in the Notre Dame School of Paris), and music of other cultures (e.g., African music) for even longer. It is proposed here that each part in a multipart texture be called an *integrant pattern*, and the structure that emerges when these parts are combined be called an *aggregate pattern* (see Figure 1.14 and Track 17 for an example of the type of multipart texture that is investigated experimentally later in Chapter 6). The concept of an aggregate pattern is similar to Riemann's (1903) 'rhythmic resultant', which is "the vertical summation of any simultaneously sounding rhythmic patterns" (Yeston, 1976, p. 26).

```
Integrant 1    x-----------x---x--------------xx-------x---x-x-x
Integrant 2    ------o-o-o---o------ooooooo-oo-----o--o---------

Aggregate      v-----v-v-v-v-v-v----vvvvvvv-vvvv---v--vv---v-v-v
```

**Figure 1.14:** Two integrant patterns and the aggregate pattern that results when they are presented concurrently.

The ubiquity of multipart rhythmic textures ensures that much musical rhythmic behaviour involves the use of some form of divided attention strategy – whether it be in the context of a concert-goer simultaneously listening to rhythmically differentiated melodic and accompanimental parts, or an ensemble performer simultaneously paying attention to the part they are playing and the parts played by others. The process of simultaneously attending to the features of different musical parts may be termed *integrative attending* (Jones & Yee, 1993; Jones et al., 1995). Jones and Yee (1993) point out that integrative attending involves the recognition of certain details about the relationship between events in separate parts, rather than simply being a matter of 'spreading' attention over these parts. Hence, integrative attending presumably requires a high degree of attentional flexibility.

Two types of integrative attending are distinguished here – *prioritised* and *nonprioritised* – which can be conceived as distinct 'attentional sets'. Integrative attending is prioritised if the context demands that a single part, or a subset of parts, be assigned relatively high priority and hence claims a significant portion of attentional resources. However, attention is also directed to remaining 'peripheral' parts, in conjunction with the high priority part/s, in order to derive the full musical texture. Thus, prioritised integrative attending differs from pure *selective attending*, wherein peripheral information is ignored. It is assumed here that selective attending, nonprioritised integrative attending, and prioritised integrative attending are processing strategies that can be deliberately invoked by the listener or performer.

Prioritised integrative attending is required in ensemble contexts when the performer must divide attention between his or her own part, and the overall texture that results when all parts are combined. It may also occur when only listening to ensemble music, for example, when a concert-goer focuses on a melodically or rhythmically interesting part, whilst also absorbing the whole texture. On the other hand, when integrative attending is nonprioritised, all parts are equally important to the attender. Even though nonprioritised integrative attending may be relatively rare in musical traditions that emphasise the distinction between 'melody' and 'accompaniment', it is more likely to occur when only listening, than when performing.

Only prioritised integrative attending leads to the formation of interdependent memory representations for integrant and aggregate textural levels. These representations may act as the basis for optimising behaviour in future multipart interactions. They are interdependent in the sense that structural properties of integrant and aggregate levels exert influence upon, and perhaps even bias, the perception of one another. This interdependence may serve to promote efficiency of representation.

### 1.2.3 Models of rhythmic behaviour

The domain of musical rhythm perception has inspired diverse theoretical perspectives. These include approaches based on linguistic versification (Cooper & Meyer, 1960), Gestalt ideas (Leeuwenberg, 1969; Fraisse, 1978), pattern recognition algorithms (Steedman, 1977), hypothesis testing algorithms (Longuet-Higgins & Lee, 1982; Lee, 1991), generative grammars (Martin, 1972; Lerdahl & Jackendoff, 1983; Johnson-Laird, 1991), musical intuitions about group structure (Benjamin, 1984), internal clocks and coding complexity (Povel & Essens, 1985; Essens, 1995), categorical perception (Clarke, 1987a), dynamic attentional schemes (Jones & Boltz, 1989), connectionist and oscillator networks (Desain, 1992, Gjerdingen, 1989; Large & Jones, 1999; Large & Kolen, 1994; Page, 1993), template matching (Parncutt, 1994a, 1994b), the spectral analysis of simulated neural activity (Todd, 1994). Despite their different bases, these approaches have some commonalities that arise through shared assumptions.

Approaches to rhythm perception generally attempt to describe the relationship between external musical rhythm patterns, and listeners' interpretations of these patterns. The more formal of these approaches are concerned with modelling those aspects of rhythmic behaviour that are associated with the use of grouping mechanisms such as metric frameworks. In particular, they address how rhythmic complexity influences the organisation of patterns into perceptually meaningful groups by the listener. However, individual theories typically account for only a few of the different types of rhythmic complexity described earlier in section 1.2.2. Although traditionally most theories deal with metricality and syncopation, they rarely speak directly to issues about complex meters and mixed meters. This is often justified by claims that the theories are concerned only with music from a specific genre (usually Western tonal music). Nevertheless, this limitation restricts their generality. Further, not all theories are equipped to adequately cope with expressive timing, and other real time processing issues. However, perhaps the most profoundly neglected issue relates to the perception of multipart rhythmic textures.

Formal approaches to rhythmic behaviour almost exclusively describe the perception of singlepart, as opposed to multipart, rhythmic textures. Apparently they assume that it is appropriate to generalise about the perception of multipart textures from their singlepart models. This assumption is questionable on the basis of the fact that, as noted earlier, much rhythmic behaviour requires the use of a divided attentional strategy, such as integrative attending. Although some approaches do address the perception of polyrhythms, which qualify as multipart structures, these usually assume that listeners employ a passive attentional strategy like nonprioritised integrative attending, rather than engaging active attentional strategies like prioritised integrative attending. Models that fail to take into account the attentional flexibility that this process requires may have difficulty when empirically tested in musical contexts beyond a simple singlepart texture. Given the pervasiveness of multipart textures, this limitation affects the generality of these models, and thus seriously challenges their ecological validity. It is noteworthy that such shortcomings are occasionally acknowledged by the model developers themselves. For instance, Todd (1994, p. 56) admits that his model is “not able to resolve polyphony and only gives an account of the overall rhythmic effect”.

The assumption that models of singlepart rhythmic behaviour will generalise to multipart contexts is also limiting in that it has produced models that account for rhythmic behaviour in a somewhat piecemeal fashion. Whilst some models attempt to elucidate the processes that underlie a rhythm pattern’s storage in, and retrieval from, a memory system, others aim to describe the organisation of rhythmic structural information that resides (i.e., has been stored) within memory. Thus, whereas some models examine the role of metric frameworks in terms of their potential to assist in the organisation of a pattern as it unfolds in time, others address their role in the delineation of memory structures. This leads to differing interpretations of experimental findings relating to the relationship between metricality and the accuracy of rhythmic behaviour. Typical findings – such as that behavioural accuracy is greater in response to metrical, than nonmetrical, patterns – are taken to indicate that metrical patterns are *processed* more efficiently than nonmetrical patterns, or that they are *represented* more efficiently in memory, depending on the approach. The fact that different approaches to rhythmic behaviour emphasise processing and representation factors to differing degrees is suggestive of two broad classes of models. This dichotomy manifests itself in healthy competition between what may be called *procedural models* and *representational models* of rhythmic behaviour.

#### 1.2.3.1 Representational models

Representational models depict rhythmic behaviour by proposing algorithms for compiling symbolic codes that are assumed to describe internal representations of rhythm patterns in memory. These models generally claim that the accuracy of rhythmic behaviour is a function of the efficiency of these symbolic codes. In this conception, representational efficiency is basically related to the number of symbols, or rules, that are required to describe a pattern's structure. That is, representational codes are efficient to the extent that they are concise. Therefore, hierarchical structures, like metrical patterns, engender efficient representation and, consequently, accurate behaviour, because their recursive properties generate redundancies that can be accounted for by relatively few rules.

In a review of several early coding-based models (e.g., Simon & Sumner, 1968; Restle, 1970; Leeuwenberg, 1969), Jones (1985) points out that they usually describe temporal organisation in terms of serial order event relations, which they specify according to rules that are essentially non-temporal, or static, in nature. Nevertheless, some recently developed representational models, such as the 'internal clock' model of Povel and Essens (1985), have been particularly influential as a means of conceptualising rhythmic complexity as related to hierarchical temporal structure. This model will be considered here in detail.

Povel and Essens (1985) assume that "in perceiving a temporal pattern, a listener tries to generate an internal clock which is subsequently used as a measuring device to specify the temporal structure of the pattern" (Essens & Povel, 1985, p. 1). The internal clock can be viewed as a metric framework where the clock unit (i.e., the interval between clock ticks) may potentially represent different metric levels, depending on presentation rate. At relatively slow rates, the clock unit corresponds to pulse periods at the beat-level of a metric hierarchy, and the subdivision of this unit implied by the placement of pattern elements represents a sub-beat-level pulse period. However, at relatively fast rates, the clock unit may correspond to bar-level pulse periods, and the implied subdivision defines a beat-level pulse period. Whether an internal clock is induced, and, if so, the duration of the clock unit and its subdivision, are determined by both the placement of pattern elements and the distribution of accents (Povel & Essen, 1985). A clock will be induced if (a) the structures defined by clusters, or figural groups of pattern elements are divisible into units of equal duration, and (b) accents occur periodically. These conditions suggest that clocks are more likely to be invoked in response to metrical patterns than to nonmetrical patterns (Essens & Povel, 1985).

When an internal clock is induced, coding the pattern involves compiling a symbolic description of how clock units are subdivided by pattern elements. The codes related to metrical patterns contain information about (a) the metric of the clock level and lower levels implied by the subdivision of clock intervals by pattern elements, and (b) the relationship between groups of pattern elements and clock metric pulsations (Essens, 1995). Codes related to nonmetrical patterns include information about the figural features of perceptual groups of elements (such as number of elements in each group), and the serial order in which these groups occur, but not about the duration of intervals between these groups (Povel & Essens, 1985). As such, the codes associated with metrical patterns are at the same time more comprehensive and more efficient (as they capitalise on the recursiveness of hierarchical structures) than those associated with nonmetrical patterns. This has implications for understanding some aspects of rhythmic complexity.

Essens (1995, p. 525) states that, in the internal clock model, “it is implicitly assumed that clock and subdivision characteristics contribute independently to the coding complexity of the sequence”. ‘Clock characteristics’ refer to “the quality of the match of the clock with the sequence” (Essens, 1995, p. 525), in terms of whether or not clock ticks coincide with accents produced by pattern elements. The quality of this match may vary, as more than one clock (each differing in unit duration and phase, i.e., location of the first tick relative to the sequence) can be associated with the same pattern. In fact, the internal clock model provides an algorithm for predicting which of several hypothetical clocks is most strongly induced by a given pattern. Clock induction strength is computed by weighting the amount of counterevidence met by each candidate clock when matched against the pattern. Counterevidence includes clock ticks that coincide with unaccented pattern elements and silences. The clock that accumulates the least counterevidence is termed the *best clock*, and corresponds to the meter of best fit. Patterns where there is a high amount of coincidence between accents and the ticks of the best fitting clock are less complex than patterns where the amount of coincidence is low.

With regard to 'subdivision characteristics', the clock unit may be subdivided into equal intervals, unequal intervals, or it may be empty. Unequal subdivisions are more complex than equal subdivisions or empty intervals, since coding complexity is related to the number of symbols needed to describe the contents of the subdivision. The internal clock model is supported by empirical findings that indicate agreement between the model's categorisation of patterns according to clock induction strength and behavioural measures including reproduction accuracy and complexity judgements (Essens & Povel, 1985; Povel & Essens, 1985).

Povel and Essens' (1985) internal clock model allows the formal description of various types of rhythmic complexity. Clock and subdivision characteristics are useful concepts for understanding some aspects of metricality and complex meters (although the latter are not specifically addressed in expositions of the internal clock model). In addition, syncopation, hemiola, and polyrhythm can be explained by the idea that rhythmic tension arises when pattern deviations demand the adjustment of a clock, or when structural ambiguity permits a pattern to be represented by two or more codes that are equally efficient (Povel, 1984; Povel, 1985). However, the internal clock model encounters difficulties with other phenomena related to rhythmic complexity.

Povel and Essens' (1985) conceptualisation of rhythmic complexity implies that there is a factor within which the qualities 'metrical' and 'nonmetrical' exist as discrete categories. In this view, complexity is a more or less continuous dimension, but there is a perceptual break in this continuum at the boundary between the metrical and nonmetrical categories. Given that complexity is defined according to codes that describe the relationship between a pattern and an internal clock, Povel and Essens' (1985) model can only be used to specify the relative complexity of several given patterns when they belong to different categories (i.e., metrical versus nonmetrical), or when they all belong to the metrical category (patterns may vary in the degree too which their structure is accommodated by their best fitting meter). Their approach does not provide any guidelines for measuring the relative complexity of nonmetrical patterns, which are assumed to be represented by imprecise, undistinctive figural codes. Nevertheless, although there is evidence that nonmetrical patterns are perceived as figural groups without regular temporal relations (Bamberger, 1980; Handel, 1998; Smith, Cuddy, & Upitis, 1994), behavioural accuracy has been observed to vary systematically when nonmetrical structure is manipulated (Handel, 1992). A related point is made by Jones and Yee (1993), who question whether Povel and Essens' figural coding schemes are rich enough to accommodate the variety of nonmetrical structures that occur in music (also see Clarke, 1987b).

Critical attention has also been directed towards the ability of the internal clock model to account for metricality-related phenomena such as mixed meter. Franks and Canic (1991) suggest that, at tempos that call for clock units that (under other circumstances) correspond to bar-level metric units, sequences best fitting mixed meters fail to induce a clock, and consequently are not coded as metrical patterns. This is presumably because the irregular accent patterns that underlie the variable bar unit durations that characterise mixed meters are incapable of inducing internal clocks, in which ticks are, by definition, isochronous. Polymetric structures present even greater difficulties for the internal clock model.

Some further limitations of Povel and Essens' (1985) approach relate to its emphasis upon representational, rather than processing efficiency, and to the nature of the representations it postulates. Jones (1985, p. 206) points out that coding-based approaches such as the internal clock model "fail to accommodate perceptual changes that occur with rate variations", as in auditory streaming. This deficiency is perhaps due to the neglect of certain real time constraints that operate upon ecologically-driven processes associated with locating and distinguishing sound sources (see Bregman, 1990). Further, although Povel (1984, 1985) acknowledges that music is rarely performed with mechanical regularity, the internal clock model does not address the processes that underlie the encoding of expressive timing deviations, nor does it describe representational codes that are capable of accommodating the results of such processes. This omission is noteworthy, as findings that these deviations are systematic and reproducible (see 1.2.2.3) suggest that they are represented in memory. Finally, it is unclear whether an approach based on the efficiency of static symbolic codes can parsimoniously describe prioritised integrative attending, through which interdependent representations for integrant and aggregate aspects of multipart rhythmic textures come to coexist.

It can be argued that the inability of Povel and Essens' (1985) model to account for auditory streaming, expressive timing, and prioritised integrative attending in multipart contexts derives from failure to recognise certain considerations of ecological adaptiveness. These considerations relate to demands that are placed upon the perceptual and cognitive mechanisms responsible for processing temporal structures in which complexity arises due to factors such as rate variation or textural density. Basically, the process of perceptually organising such structures requires mechanisms with sufficient flexibility to appreciate functionally significant deviations from regularity. This flexibility in processing is precluded by the exclusively top-down nature of Povel and Essens' approach, in which pre-existing clock-like timing mechanisms are compared to whole sequences in a template-matching routine, rather than being derived bottom-up from structural features that emerge as the sequences unfold. Although Povel (1984) does acknowledge processing issues that arise from the sequential nature of temporal presentations, the constraints imposed by these considerations are not formally incorporated in the internal clock model.

The problems regarding Povel and Essens' (1985) inadequate treatment of processing issues impact upon their conception of representational efficiency. Lee (1991, pp. 73-74) argues that representational models

> "take no account of the fact that the listener has to build up a metrical interpretation in the course of listening to a sequence; he or she does not wait until the sequence has finished before reaching a decision. The problem is not merely one of ecological validity: there are strong grounds for believing that processing factors actually determine, to a greater or lesser degree, a listener's final choice of interpretation for a given sequence".

This implies that memory representations of sequences contain more information about the real time aspects of the interaction between processing mechanisms and temporal structures than is embodied in Povel and Essens' symbolic codes. Thus, the neglect of processing related issues seriously undermines the ability of representational models to describe the bases of behaviours associated with complex temporal structures that are pervasive in the musical rhythmic environment.

Some notable attempts have been made to address the shortcomings of representational models. For example, Parncutt (1994a) has outlined a representational model that overcomes some real time limitations by incorporating routines that account for primacy and recency effects, as well as absolute durational limits on attentional processes.

#### 1.2.3.2 Procedural models

Procedural models describe the action of perceptual and cognitive processes that are engaged during the encoding and retrieval of temporal sequences. In contrast to representational models, procedural models typically focus upon the role of processing efficiency in determining the accuracy of rhythmic behaviour. These models interpret patterns by examining successive temporal intervals, in a progressive fashion, with a view to detecting structural regularities that have potential to serve as bases for metric frameworks. It is usually claimed that the hypothetical metric units are derived through a process involving the generation of temporal expectancies that are based on the duration of preceding intervals. Processing is considered to be efficient to the extent that these expectancies are confirmed by subsequent events. As a consequence of their bottom-up approach (which does not permit a static view of pattern structure), procedural models are generally able to account for real time phenomena more successfully than representational models. However, procedural models differ in terms of the degree to which they incorporate real time constraints. This difference appears to be related to whether the processes described by the models are algorithmic (where the changes in sequence structure that occur across time are viewed as a series of discrete steps) or dynamic (where structural changes are considered to be continuous).

##### *1.2.3.2.1 Algorithmic-procedural models*

Longuet-Higgins and Lee (1982) and Lee (1991) adopt an algorithmic approach in their procedural models of rhythm perception. These models assume that listeners work through a sequence interval by interval in a step-wise manner from left to right, developing hypotheses about its underlying metric structure. At each step in the process, hypotheses about metric units are tested and subsequently confirmed or revised. These hypotheses are based upon the assumption that relatively long intervals are good candidates for major metric units. Both models begin by specifying low-level metric units, upon which they build the most appropriate, or best fitting, metric hierarchy by modifying either the duration of the low-level units (i.e., period), or their position relative to the sequence (i.e., phase).

Longuet-Higgins and Lee's (1982) model attempts to identify the meter that a given sequence best fits by initially inferring a hypothetical metric pulse unit from the interval defined by the first two elements of the sequence, and then either combining, expanding, or phase-shifting the units based upon the metric hypothesis, depending on whether it is confirmed or violated by subsequent events. If the original metric hypothesis is challenged, the proposed unit is expanded and/or moved in relation to the pattern intervals, so that the problematic structural element is accommodated. When a metric hypothesis is confirmed, the model moves up the metric hierarchy by predicting an additional pulse based on double the established metric unit (reflecting a preference for 2:1 ratios in rhythmic behaviour, as noted by Fraisse, 1978, and Essens & Povel, 1985). This process of predicting, revising, and confirming iterates through the sequence. The model ultimately yields predictions about the location of bar-level pulses, but does not explicitly address pulses at any other metric level (e.g., beat or beat subdivisions).

Several limitations have been identified with Longuet-Higgins and Lee's model. Povel and Essens (1985) point out that it always supplies a metrical interpretation. Therefore the model in unable to simulate the qualitative differences that have been observed between metrical and nonmetrical behaviours. In addition, Povel and Essens argue that the model does not allow accents (other than the durational variety) to play a role in determining meter. This is perhaps symptomatic of the model's failure to distinguish between notated and perceived meter (see Parncutt, 1987). Lee (1991) has identified some further aspects of Longuet-Higgins and Lee's model that are unfaithful to the rhythmic behaviour displayed by human listeners. His complaints relate mainly to findings that (a) sequences are not always interpreted according to their best fitting meter, (b) listeners typically experience more than one pulsation level simultaneously, and (c) tempo affects the interpretation of a sequence. Lee (1991) has reformulated Longuet-Higgins and Lee's (1982) model with these observations in mind.

Lee's (1991) version of the model differs from the earlier version in several respects. Metrical ambiguity is accounted for in Lee's initial statement of the model by including a variable in the algorithm that determines how tolerant it will be to violations of metric hypotheses. Different settings of this variable allow more than one interpretation of a given sequence. However, when discussing his model in terms of its psychological reality, Lee introduces a modification through which multiple interpretations of a sequence are formed in parallel, and the final interpretation is chosen according to some ideal value of the tolerance variable. Another feature of Lee's revised model is a routine for discovering metric levels lower than the one initially hypothesised. This allows the hierachical structure of meter to be more fully realised. However, perhaps the most significant revision introduced by Lee is the facility to accommodate tempo effects. The processes associated with revising and combining hypothetical metric units aim to establish unit durations that lie within boundaries defined by something like the existence region of pulse sensation. These limits also affect the metric violation threshold by influencing the location of the point at which violations of a metric hypothesis cease to be efficacious. Thus, the model's interpretation of a sequence may vary with presentation rate.

Although Lee's (1991) model supports a distinction between the interpretation of metrical and nonmetrical patterns, it does not propose any method for parsing nonmetrical patterns. When the process of revising and combining metric units breaks down, it is simply the case that "parsing is abandoned" (Lee, 1991, p. 100). Thus, like Povel and Essens' (1985) representational model, Lee's model does not generalise to music that is not organised according to metric principles. Lee's model can not account for complex meters for similar reasons: it assumes, as did Longuet-Higgins and Lee's (1982, p. 124) earlier model, that "for any given [metric] level the units on that level must all be of the same length".

However, Lee's model is well suited to the task of describing the processes that underlie syncopation. In particular, the inclusion of the tolerance variable, in combination with the model's sensitivity to tempo effects, grant it the potential to predict the location of the metric violation threshold and to describe the perception of hemiola. Furthermore, Lee's model may be able to deal with the perception of mixed meters if the tolerance variable adopts a value that does not allow much violation of metric hypotheses before the interpretation is forced to change. Lee implies that the relaxation of the tolerance variable may also play a role in the appreciation of expressive timing deviations. In addition, assumptions about the simultaneous formation of multiple interpretations, and about tempo constraints on the selection of metric units, fit well with empirical observations of polyrhythmic, and perhaps even polymetric behaviour. Moreover, it is conceivable that the model could be adapted to incorporate routines for processing pitch interval information, and thus simulate auditory streaming effects. Nevertheless, a means of extending Lee's model to address prioritised integrative attenting in multipart contexts is not readily apparent. Indeed, any algorithmic-procedural model may experience difficulties in this regard that are comparable to those experienced by representational models.

#### *1.2.3.2.2 Dynamic-procedural models*

Algorithmic-procedural models are not suited to describing prioritised integrative attending because they specify processing activity as an ordinal series of discrete steps. They do not consider the real time activity that intervenes between these steps. Therefore, the processes described by algorithmic models lack continuity and flexibility, which makes them unlikely candidates for the processes that underlie activities such as prioritised integrative attention. It is of historical note that William James presents a related argument in his discussion of the importance of recognising the “transitive parts” of the “stream of thought” (James, 1890/1950, pp. 237-248). Recent support for the validity of this line of argument is provided by advocates of the dynamical approach to cognition.

In an exposition of the dynamical approach, Van Gelder and Port (1995, p. 2) state that “Cognitive processes and their context unfold continuously and simultaneously in real time”. They argue that it is important for models of cognitive processes to recognise that the state of a cognitive system undergoes continuous changes, and that these changes occur across real (continuous) time. The need to formally acknowledge the continuity of processing becomes paramount when the target behaviour involves what Van Gelder and Port (1995) term *multiple simultaneous interactions*. In these interactions, which are exemplified by prioritised integrative attention, separable yet interdependent aspects of an event are processed in parallel. The processes that act upon different components of the event interact in the sense that they each influence one other. Van Gelder and Port (1995) suggest that this interactive relationship can be described more elegantly by differential equations, which are used to specify the trajectories of continuous changes in a system’s state, than by computational algorithms.

McAuley (1994) and Port, Cummins, and McAuley (1995) have applied the dynamical approach to auditory temporal event processing in adaptive oscillator models. The dynamical views are also compatible with attempts by Desain (1992), Gjerdingen (1989), Page (1993), and Large and Kolen (1994) to model rhythmic behaviour within a connectionist framework. Todd’s (1994) ‘primal sketch’ model of rhythmic grouping, which is based on a sophisticated understanding of the physiology of the auditory and motor systems (also see Todd, 1996), exemplifies another class of model that embraces dynamical concerns (although some of its formal assumptions are very different to those of orthodox dynamical models of rhythm). However, perhaps the most fully developed account of temporal event processing based on dynamical concepts is the dynamic attending theory of Mari Riess Jones (Jones, 1976; Jones & Boltz, 1989; Large & Jones, 1999).

The dynamic attending approach to rhythmic behaviour has its origins in Jones' (1976) ecologically-based theoretical framework for understanding behaviours related to a broad range of (not necessarily musical) temporal events. Jones' theory describes how the processing of such events is affected by their temporal structure. Adopting this approach, Jones and Boltz (1989) specify rhythmic complexity according to how the temporal coherence displayed by a sequence influences the type of attentional strategy it supports. According to Jones and Boltz, temporal coherence is related to the degree to which pitch-related, dynamic, and temporal accents define periodicities that suggest hierarchically nested structural levels. In *temporally coherent events* "hierarchical time structures display regular, ratio-based temporal nestings within an event's total duration, as well as constant additive modulations to this ratio base" (Jones & Boltz, 1989, p. 465). The introduction of these additive time transformations usually involves modifying the period at a single level of the hierarchy such that its isochrony is disrupted. However, if carried out systematically, these modifications often can be accommodated by postulating a 'missing' hierarchical level that subsumes the modified level, and provides it with a ratio-based link to the rest of the hierarchy. On the other hand, *temporally incoherent events* are "nonhierachical time structures [that] do not display simple temporal recursivity… they are more complex because ratio and additive time transformations are inconsistently applied" (Jones & Boltz, 1989, p. 466). In the domain of musical rhythm, temporal coherence is manifested as metricality: metrical patterns are coherent whereas nonmetrical patterns are incoherent.

Jones and Boltz (1989) claim that temporally coherent and incoherent events afford different attending modes. Temporally coherent events support 'future-oriented attending', where attention is cast over focal periods suggested by the event's structure. Thus, attention to metrical patterns is characterised by a process of attunement, whereby a listener's biologically-based rhythms, or 'attentional oscillators' (Jones & Yee, 1997; Klein & Jones, 1996; Large & Jones, 1999), become synchronised with some referent focal period/s implied by the pattern's structure. According to Jones & Boltz (1989, p. 470), attunement "involves a synchronous interplay between an attender and an event in which the former comes to partially share the event's rhythmic pattern. This involves an enlistment of organismic rhythms whose frequencies and amplitudes can mirror those of an event…". The identity of the biological mechanism underlying attunement is presently unknown. However, it is worth noting that evidence for multiple oscillators has been found in interval timing behaviour in rats (Crystal, 1999) and human EEG data (Treisman, Cook, Naish, & MacCone, 1994), and that, as noted earlier in section 1.2.1.2, the cerebellum has been implicated in timing functions (Ivry & Keele, 1989).

After a referent period is established through attunement, other periods based on ratio time transformations of the referent are determined. Thus, attentional oscillators may become phase-locked in a way reflecting the ratios defined by beat- and bar-level divisions (and possibly beat subdivision-levels) of metric frameworks: e.g., 4:1 for quadruple patterns; 3:1 for triple patterns. This pattern of oscillator activity embodies temporal expectancies that automatically guide attending (Jones, 1982, 1990). So long as these expectancies experience only a limited degree of violation, processing will be efficient and attending will be flexible.

According to the dynamic attending theory, frequent failures of the attunement process are experienced with temporally incoherent events, such as nonmetrical patterns, due to a high degree of expectancy violation (Jones & Boltz, 1989). Consequently, nonmetrical patterns elicit a more 'analytic' mode of attending, wherein elementary mnemonic strategies (e.g., figural grouping, counting, and associative labelling) are employed to establish low level relationships among adjacent pattern elements. These mnemonic strategies are effortful, and hence diminish efficiency and flexibility in processing. (Jones & Boltz also use the term 'analytic attending' to refer to the process of attending to relatively short focal periods in hierarchical events).

Formal predictions about magnitude of expectancy violation, and its effects upon attending, are generated by a *temporal contrast* model, which quantifies "The difference between observed and expected focal periods…" (Jones & Boltz, 1989, p. 473). Basically, the temporal contrast model makes predictions about (a) whether a sequence of events will elicit future-oriented or analytic attending, and, if the former is the case, (b) the magnitude of the constrasts that particular expectancy violations will produce.

The temporal contrast model is supported by observations from a broad range of experimental paradigms, including time estimation (e.g., listeners indicate the temporal location of 'expected endings' in incomplete melodies) and detection tasks (measuring sensitivity to alterations in the timing, frequency[4], or spectral composition of tones) (e.g.,

[4] The terms 'frequency' and 'pitch' are used interchangeably in this dissertation. Although pitch is often considered to be the subjective psychological correlate of objective frequency, the relationship between the two is not yet entirely clear cut (see Moore, 1997).

Boltz, 1989; Jones & Boltz, 1989; Jones & Yee, 1997; Klein & Jones, 1996; Yee, Holleran & Jones, 1994). For example, both Yee et al. (1994) and Jones and Yee (1997) tested the ability of skilled and unskilled listeners to detect small time changes within prespecified regions of various types of regular and irregular patterns. The target regions were identical across all pattern types. In general, results indicated that temporal sensitivity was greater when the context surrounding target regions was regular, than when it was irregular. Such effects of global pattern structure on processing at specific temporal locales can be explained parsimoniously in terms of dynamic attending processes: as irregular patterns unfold in time, "accumulated violations of expectancies (contrasts) retard the entrainment of an oscillator (relative to a simple sequence) and the momentary period of the oscillator does not yield a finely focused temporal expectancy; the result is poorer temporal acuity" (Jones & Yee, 1997, p. 707). Large and Jones (1999) have recently presented an elaborate mathematical formulation of the dynamic attending theory, and have produced successful computer simulations of time estimation and discrimination behaviour.

The dynamic attending approach accounts for differences in the accuracy of behaviour related to metrical and nonmetrical patterns by proposing that the process of attending to the former is more efficient and flexible. An advantage of this approach is that it provides language that is capable of generating formal descriptions of nonmetrical, as well as metrical patterns. The concepts of ratio and additive time transformations are particularly useful in this regard. These types of time transformation are also useful for describing rhythmic phenomena characterised by systematic deviation from strict regularity.

Expressive timing deviations are one type of systematic irregularity that can be considered in terms of additive time changes and temporal contrast (Jones, 1987b; Jones & Boltz, 1989). The contrast model also has the potential to accommodate more disruptive irregularities, such as those associated with syncopation. In contrast to expressive timing, where deviations are usually confined within the boundaries of rhythm categories, syncopation is experienced when temporal contrasts arise from systematic additive time changes that cross category boundaries. In the case of hemiola, these time changes are persistent enough to temporarily define a new metric hierarchy that is inconsistent with an established hierarchy. Complex meters are also characterised by additive timing modulations (Jones, 1990). However, London (1995) discusses some problematic instances of complex meter where the relationship between the referent period and other metric levels can not be specified by simple ratios, or there is no evidence of an isochronous referent period. London challenges the dynamic attending approach by questioning the utility of the notion of a referent level in these situations. He suggests that, rather than finding a referent and then building a hierarchy around it, all levels of a complex metric hierarchy must be generated simultaneously. Mixed meters may present similar difficulties, although it is likely that in many cases they may be processed relatively efficiently through the use of analytic attending strategies aimed at low level metric units such as beat-level subdivisions. Nevertheless, the dynamic attending approach fares quite well with the structural aspects of the above irregular phenomena. Furthermore, the temporal contrast model is well equipped to account for the experiential aspects, including the aesthetic appeal, of such phenomena.

The dynamic attending approach has also been used as a framework for understanding polyrhythmic behaviour (Jones et al., 1995) and auditory streaming effects (Jones, 1976; Jones, 1985; Jones et al., 1981; Jones & Yee, 1993). In discussions of these phenomena, the likelihood of integrated versus segregated percepts is assumed to be affected by real time rate related constraints associated with a *serial integration region* and a *dominance region*. Both regions bear resemblance to the existence region of pulse salience in the sense that they influence the selection of focal periods that control attending, and thus determine the position of group boundaries. Jones (1992, p. 97) describes the serial integration region as "a neighbourhood in pitch-space and time that reflects the most coherent extensions of current pitch/time relations unfolding in a pattern". Rates of pitch change that fall within the boundaries of the serial integration region encourage sequences to be perceived as integrated, whereas rates outside the serial integration region promote the segregation of sequences. The size of the serial integration region is influenced by attending mode (it is larger for future-oriented attending than for analytic attending) (Jones, 1992), and therefore is presumably affected by the so-called dominance region. According to Jones and Boltz (1989), the dominance region specifies the number of hierarchical focal levels (typically four or five) across which attention can be shifted in accordance with a listener's goals. Such shifting is an effective strategy for resolving structural ambiguities – such as those associated with the figure/ground aspects of polyrhythms – by allowing a pattern to be considered from different temporal perspectives (Jones, 1987b, 1990; Jones and Boltz, 1989).

Notably, the emphasis placed by the dynamic attending approach upon the benefits of employing flexible attentional strategies have encouraged its application to some issues related to the perception of multipart rhythmic textures. Jones et al. (1995) examined the effects of attentional set (integrative[5] or selective attending) and pitch separation (narrow or wide) between the two streams of a 3:2 polyrhythm, on ability to detect timing changes to a tone in the one of the streams. They found that when listeners were instructed to employ a (nonprioritised) integrative attentional strategy (i.e., interpret both streams as a single sequence), detection of timing changes was better with narrow, as opposed to wide pitch separations. On the other hand, selective attending to a single stream, which was nominated as potentially containing the target timing change, produced more accurate responses when pitch separation was wide. These findings imply that it is easier to engage in integrative attention when the pitch separation between streams is narrow (which can be explained by appealing to Jones', 1976, serial integration region).

In another study using multipart patterns as stimuli, Klein and Jones (1996) were interested in how the temporal coherence of the relationship between concurrent high- and low-pitch tone sequences, as well as attentional set (divided versus selective attending), affects the ability to detect alterations to the tones' harmonic spectra. Divided attention was encouraged by instructing participants to respond to spectrally altered target tones in both the high- or low-pitch sequences. Selective attention was encouraged by asking participants to respond only to target tones in the high-pitch sequence. Accuracy at target detection was compared across conditions featuring stimuli that differed in terms of the complexity of the ratio between periods marked by the isochronous high-pitch sequence, and those marked by the low-pitch sequences (which were not necessarily isochronous). It was generally found that when the temporal relationship between sequences was relatively simple, performance was best in conditions where listeners were encouraged to use a divided, rather than a selective attentional strategy, whereas the opposite was the case for complex inter-sequence relationships. Klein and Jones (1996) explain this in terms of the degree to which the pattern of oscillator activity encouraged by attentional set is compatible with oscillator activity implied by the temporal relationship between sequences. Thus, tight oscillator connections encouraged by divided attention facilitate performance in simple patterns, which are assumed to induce strongly connected oscillators, whereas solo oscillator activity encouraged by selective attending conditions facilitates performance in complex patterns, where weakly connected oscillators are invoked.

[5] The type of integrative attending studied by Jones et al. (1995) was nonprioritised.

The experimental findings of Jones et al. (1995) and Klein and Jones (1996) demonstrate that the dynamic attending approach has the capacity to account for some examples of multipart rhythmic behaviour. However, they do not allow strong conclusions to be drawn about the processes that underlie integrative attending (prioritised or nonprioritised) in multipart textures where integrant patterns are highly rhythmically differentiated. In particular, it remains unclear how integrative attending would proceed in situations where potential referent periods are less obvious than they were in the predominantly isochronous sequences used in these experiments, or where integrant patterns are nonmetrical. In addition, the procedures used by Jones et al. (1995) and Klein and Jones (1996) did not demand prioritised integrative attending, where both integrant and aggregate textural levels are attended to in a parallel fashion. Their tasks instead required that listeners monitor either an integrant *or* the aggregate aspect. Further, the studies do not directly address the ability of listeners to form interdependent representations of integrant and aggregate aspects of multipart patterns. The cognitive demands associated with the target detection tasks used are more closely related to on-line processing, rather than representational considerations: ability to monitor, rather than to memorise, was of interest. This is consistent with the tendency to emphasise processing efficiency in dynamic attentional accounts of rhythmic behaviour.

#### 1.2.3.3 The ecological validity of representational and procedural models compared

Representational, algorithmic procedural, and dynamic-procedural models are differentially sensitive to considerations of ecological adaptiveness. This affects their capacity to describe behaviour related to the types of temporal structure that define musical rhythmic environments. The status of each model with respect to its ability to account for various definitive rhythmic phenomena is summarised in Table 1.1. This summary clearly indicates that dynamic-procedural models fare better than algorithmic procedural and representational models when it comes to the musical phenomena in question.

**Table 1.1:** Status of different models of rhythmic behaviour with respect to various rhythmic phenomena.

| | **Representational** | **Procedural** | |
|---|---|---|---|
| | | Algorithmic | Dynamic |
| | *Povel & Essens* | *Lee* | *Jones & Boltz* |
| Metricality: | | | |
| Distinction between metrical and nonmetrical behaviour | ✓ | ✓ | ✓ |
| Metrical patterns | ✓ | ✓ | ✓ |
| Nonmetrical patterns | × | × | ✓ |
| Syncopation | ✓ | ✓ | ✓ |
| Hemiola | ✓ | ✓ | ✓ |
| Complex meter | ✓ | × | ? |
| Mixed meter | ✓ | ? | ? |
| Expressive timing | ? | ✓ | ✓ |
| Polyrhythm | ✓ | ? | ✓ |
| Polymeter | × | ? | ✓ |
| Auditory streaming | × | ? | ✓ |
| Multipart rhythmic textures | × | × | ? |

Note:
✓ indicates that the phenomenon is either explicity or implicitly accounted for by the model
? indicates that the model appears to have the potential to account for the phenomenon
× indicates that the means by which the model might account for the phenomenon is not readily apparent

Although representational and algorithmic-procedural models each have unique limitations, they also share two main shortcomings: (a) they do not produce formal descriptions of nonmetrical patterns, and (b) they are unable to simulate integrative attention in multipart contexts. The first limitation appears to stem from tacit constraints associated with implementing the models as algorithm driven computer programs that use static symbolic codes and process information in discrete steps. The second has similar roots, but relates more specifically to a failure to incorporate appropriate real time constraints relating to both *timescale* and *continuity*.

It is conceivable that these shortcomings may be remedied by adding new assumptions and routines to the models, although the results of such cosmetic modifications might be inelegant and implausible. Dynamic procedural models do not seem to have these problems. This is largely due to the formal recognition of real time constraints ensuring that different types of temporal structure afford different attentional strategies, and that temporal sequences and processing mechanisms undergo synchronous state changes that are continuous rather than discrete. Thus, the processes described by dynamic procedural models are sufficiently varied and flexible to handle a diverse range of rhythmic phenomena. Most notably, they have proven successful in accounting for certain aspects of multipart rhythmic behaviour. However, their ability to describe the prioritised form of integrative attending behaviour – where integrant and aggregate aspects are processed in parallel, and represented interdependently in memory – has not yet been demonstrated. A detailed investigation of prioritised integrative attending will be presented in the following chapters of this dissertation.

#### 1.2.3.4 The importance of considering both representational and processing efficiency

The extent to which the different classes of model are ecologically valid varies as a function of their goals. Representational models aim to produce descriptions of metrical representations. Algorithmic-procedural models attempt to describe the processes that result in such metrical representations. The goals of these two brands of model are qualitatively similar: in both cases the ultimate objective is to supply a metrical interpretation. However, dynamic-procedural models have a qualitatively different goal – the description of the processes that mediate real time interactions between individuals and temporal events – resulting in a more explicit commitment to considerations of ecological adaptiveness. The different goals of the models result in the emphasis of different aspects of the relationship between rhythmic complexity and the efficiency of rhythmic behaviour. As mentioned earlier, representational models emphasise how rhythmic complexity affects the efficiency of symbolic codes, where fewer symbols indicate more efficient representation. Algorithmic-procedural models adopt a similarly quantitative approach, but emphasise efficiency in terms of number of processing steps required to arrive at some ideal metrical interpretation. Finally, dynamic-procedural models emphasise processing efficiency by postulating qualitatively different modes of attention that vary in flexibility. Focusing upon these distinct types of efficiency motivates different conceptions of the role of metric frameworks.

The relative contributions of representational efficiency and processing efficiency to the accuracy of rhythmic behaviour is not a trivial issue, as they have implications for the precise role of metric frameworks. This echoes Rumelhart and Norman's (1985, p. 20) concern with the notion that representational systems include both *representations* and the *processes* that act upon them: "The processes that evaluate and interpret the representations are as important as the representations themselves". This idea is embodied in connectionist models, wherein representation and processing are inextricably linked, as both are realised through weighted patterns of connectivity between individual units within neural networks. Notably, representation and processing are explicitly recognised in some models that address temporal event perception (e.g., Elman, 1990).

To focus solely on the efficiency of representations implies that meter functions to provide a frame of reference within which to specify the temporal organisation of events represented in memory. This limits the facilitative role of meter to that of a static template, thus precluding the explanation of real time phenomena. On the other hand, to focus solely on processing efficiency produces insufficient explanations of the persistence of complex, multidimensional memory representations of music. That is, theories devoted to encoding and retrieval processes do not necessarily account for the mediating memory representations. Evidence for the importance of such representations has come to light in studies of how musical behaviour is affected by episodic and implicit memories (see Crowder, 1993a), as well as by abstract knowledge-based schemas, such as those reflecting the structure of metric hierarchies (Palmer & Krumhansl, 1990).

Palmer and Krumhansl (1990) investigated how abstract knowledge of meter affects the representation of temporal sequences in memory. They used a temporal discrimination task requiring judgements to be made about whether standard and comparison events occurred at the same temporal location relative to explicit metric bar-level markers. Listeners were instructed to imagine beat-level pulsations that divided the explicit bar-level markers by ratios reflecting different metric frameworks. Thus, the task involved accessing representations of metric structure. Ability to make the required judgements was tested at a variety of strong and weak metric locations. Results indicated that "events occurring in metrically strong locations were more easily recognized and less likely to be confused with events occurring in neighbouring temporal locations" (Palmer & Krumhansl, 1990, p. 738). These findings provide evidence that the perception of temporal sequences may be biased by representations of metric structure that have been previously stored in memory. The importance of considering the representation of temporal structure is also underscored by findings that performers are able to remember and reproduce expressive timing deviations despite the categorical nature of rhythm perception. However, the notion of representional efficiency may be most useful in explaining the coexistence of memory structures related to integrant and aggregate aspects of multipart patterns.

The dilemma of neglecting either real time phenomena or memory representations can be solved by emphasising both representational and processing efficiency. This double-barrelled approach implies that metric frameworks function to promote attentional flexibility, as well as acting as a temporal frame of reference. A similar proposal emerges from the confluence of views about ecologically adaptive temporal behaviour expressed by Michon (1985) and Jones and Boltz (1989).

Michon (1985) claims that forming internal representations of external temporal events enables adaptive behaviour by allowing an organism to function independently of the external events. Furthermore, he argues that real time correspondence between external events and internal representations is achieved by a synchronisation process (which can be viewed as qualitatively similar to attunement). According to Michon (1985, p. 29), synchronisation frees the organism to “do other things in between the instants at which perfect coincidence is crucial”. Jones and Boltz (1989) discuss possible benefits of this flexibility in situations that involve attunements related to temporally coherent motor behaviour, or body movements.

Jones and Boltz (1989, p. 466) state that the temporal predictability of motor gestures “not only affords a basis for individual motor coordination and self synchrony, it also means that visual action patterns created by one individual can support various interactive nonverbal communications with others, including turn-taking behavior, dance, nurturing, and prey-stalking, all of which partake of interactional synchrony”. It seems reasonable to hypothesise that the attunements underlying metric frameworks benefit musical interactions in a similar fashion. Thus, metric framework generation may function adaptively to facilitate the attentional flexibility that is requisite for prioritised integrative attending in complex musical interactions such as listening to multipart music and performing in musical ensembles.

## 1.3 Summary

When musical rhythmic behaviour is examined from the perspective of ecological adaptiveness, it becomes apparent that it is necessary to account for a broader range of phenomena than is addressed by prominent theoretical approaches to rhythm. The most seriously neglected aspect of rhythmic behaviour is prioritised integrative attending in multipart contexts. In order to describe prioritised integrative attending, the efficiency with which multipart rhythm patterns are both processed and represented needs to be considered. It is particularly important to recognise formally how real time constraints influence the flexibility of attentional strategies employed during processing. There is evidence that the generation of metric frameworks promotes such attentional flexibility. This suggests that metric frameworks may serve as more than a temporal frame of reference that provides the basis for rhythmic organisation and grouping. They may also function to facilitate prioritised integrative attention in multipart musical rhythmic interactions.

# CHAPTER 2

# OPTIMAL BEHAVIOUR IN MULTIPART MUSICAL RHYTHMIC INTERACTIONS

This chapter examines from two perspectives the proposal that prioritised integrative attending constitutes optimal behaviour in multipart musical interactions. First, an anthropological and ethnomusicological theoretical perspective is considered. The second approach involves a survey-based study seeking to elicit the opinions of practising ensemble musicians about the importance of prioritised integrative attending and the factors that influence their ability to engage in it. Both approaches provide provisional support for the hypothesis advanced in Chapter 1 that metric frameworks play a role in facilitating prioritised integrative attending in multipart rhythmic interactions.

## 2.1 Introduction

In Chapter 1 it was claimed that the optimal attentional strategy in multipart rhythmic contexts is usually prioritised integrative attending, which is a strategy that involves simultaneous processing of target integrant and aggregate pattern aspects. However, the universality of this claim needs to be assessed, as it is likely that optimal strategies are highly context dependent. It has been found that, under certain circumstances, performance on tasks related to multipart pattern perception is better with selective attending, whereas under other circumstances, performance is better with nonprioritised integrative attending (e.g., Jones et al., 1995; Klein & Jones, 1996). Thus, specific experimental task demands clearly influence the effectiveness of different attentional strategies. However, the procedures typically employed in multipart pattern experiments inspire fairly non-musical listening goals associated with highly specific tasks such as detecting deviations in some quality of a single target tone. An attempt should be made to gain a better understanding of the goals that characterise participation in more general and realistic multipart musical interactions. To this end, the origins and features of optimal behaviour in multipart rhythmic contexts can be investigated by different methods. These include examining anthropological, ethnomusicological, and music educational accounts of rhythmic behaviour, as well as surveying the views of practicing ensemble musicians.

## 2.2 Anthropological and ethnomusicological approaches

### 2.2.1 Adaptive functions of rhythmic behaviour

There is a tradition of considering musical rhythmic behaviour in terms of adaptiveness in anthropological and ethnomusicological approaches. Leonard Williams (1967, p. 72), an ethologist working with primates (and father of renowned guitarist John Williams), establishes a link between the emergence of a “unique human conciousness” and the origins of adaptive rhythmic behaviour:

> “A fear of the ‘Unseen Spirits’ who control the food supply and the processes of generation, a moral sense and therefore a sense of guilt, the power to imitate the sounds and the rhythms of nature, a world of language, a higher intelligence from the development of tools and skills for hunting and for the making of clothes, and longer legs (which are better for dancing as well a running) – these

> are the main factors which gave rise to the disciplines of rhythmic action and chanting in the magic-ritual of the first men".

In other words, according to Williams, human primates evolved to possess rhythm perception and production systems that serve an adaptive function in terms of fulfilling a largely spiritual need.

The adaptive function of rhythmic behaviour can be observed relatively directly in cultures with well-preserved ancient musical traditions. Chernoff (1979, p. 87) points out that the Sub-Saharan Africans have developed a "complete musical system based on rhythm". This music functions adaptively in the sense that its significance derives predominantly from its sociological role: "…music is important only in respect to the overall success of a social occasion" (Chernoff, 1979, p. 67). The rhythms of African music thus facilitate the ultimate goal of musical communication. This communicative intent is made especially evident by the existence of so-called *drum language*. When drummers use drum language, "the drums actually speak the language of the tribe" (Chernoff, 1979, p. 75). That is, the articulated rhythms have specific semantic, text-based meaning. By using more than one drum, or by striking a drum in different ways, the rhythmic and tonal aspects of coherent speech patterns are duplicated. The main adaptive value of drum language is to enable communication between geographically distant communities.

The communicative ideals of African music are reflected by a predominance of multipart rhythmic textures in which individual parts are highly differentiated yet complementary. In Central African music, these textures are typically created by combining parts in accordance with what has been termed the *hocket technique* (Arom, 1991). The hocket technique is a compositional device that involves the alternation of two or more instrumental or vocal parts such that one part articulates a single sound, or a short string of sounds, while the other parts are silent. Thus, there are frequent exchanges between parts, with each part being truncated to make way for its neighbour. Rather appropriately, the term 'hocket' is related etymologically to the Latin and French words for 'hiccup'. The hocket technique produces rhythmic textures such the integrant/aggregate composite in Figure 2.1, Panel A, and Track 18. These textures are usually polyrhythmic in African music.

**A**

**B**

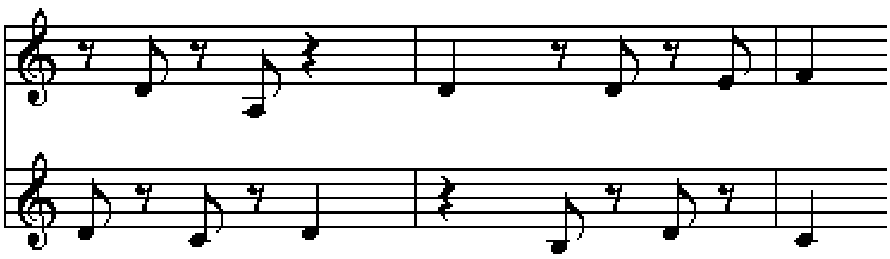

**Figure 2.1:** Examples of hocket in African music (Panel A – from Arom, 1991, p. 371) and 13th century Western music (Panel B – from Hoppin, 1978, p. 345).

The hocket technique also characterises the earliest known examples of multipart Western instrumental music, and was a popular device in 13th and 14th century Western music (Hoppin, 1978) (see Figure 2.1, Panel B, & Track 19). Riemann's (1903) concept of the rhythmic resultant is germane to both Western and African hocket. In a discussion of hocket in African music, Nketia (1962, p. 50) claims that "Each player must have a general awareness of the resultant, as well as the knack of coming in at the right moment". Similarly, "Analysis of music employing the hocket technique… must emphasise the resultant (or groups of resultants) by showing the interdependence of the separate instruments or the links, both horizontal and vertical, which bind them into an integrated whole" (Nketia, 1962, p. 51). Thus, both the performance and appreciation of African hocket relies upon recognising the relationship between integrant and aggregate patterns. Focusing on this relationship is important for practical, as well as aesthetic, reasons. One such practical goal relates to extracting the pulse.

It has been argued that the organisation of African rhythmic structure is typically specified with respect to only one level of *isochronous* pulsation (Arom, 1991; Chernoff, 1979). Consequently, the experience of African music is not accompanied by the same sensation of a regular pattern of strong and weak beats that corresponds to Western conceptions of meter (Arom, 1991). Rather, the nonperiodic accents that typify African music tend to group underlying pulsations into high-level units of unequal number (similar to complex meters – see 1.2.2.2). It is worth noting that early Western multipart music (e.g., 13$^{th}$ and 14$^{th}$ century polyphony) used similar organisational principles until the concept of meter as a strictly hierarchical, recursive structure emerged in the 16$^{th}$ century (Houle, 1987). In African multipart textures, the single pulse level is considered to be the "common denominator for all the parts" (Arom, 1991, p. 202).

The experience of pulse in African music requires a sophisticated musical sensibility that Waterman (1952) calls *metronome sense*. Metronome sense refers to a process of actively searching for a pulse in the rhythmic fabric that results when individual parts in a multipart texture are combined. Chernoff (1979, p. 95) states that "in an African musical event, one participates by integrating the various rhythms to perceive the 'beat', and the 'beat' of the music comes from the whole relationship of the rhythms rather than from any particular part". Metronome sense is an essential component of all interactions with African music, including listening, dancing, and performing. When it is exercised, participants are in fact supplying the pulse themselves. According to Chernoff (1979, p. 49) "We begin to 'understand' African music by being able to maintain, in our minds or our bodies, an *additional* rhythm to the ones we hear. Hearing another rhythm to fit alongside the rhythms of an ensemble is basically the same kind of orientation for a listener that apart-playing is for a musician – a way of being steady within a context of multiple rhythms".

The importance of focusing upon aggregate pattern structure in interactions with multipart African music suggests that an integrative attending strategy is advantageous. This is reinforced in accounts that address how African drumming is learned. Chernoff's (1979, p. 51) experiences are enlightening in this regard:

> "Only through the combined rhythms does the music emerge, and the only way to hear the music properly, to find the beat, and to develop and exercise 'metronome sense', is to *listen to at least two rhythms at once*. You should attempt to hear as many rhythms as possible working together yet remaining distinct, and you can judge or train yourself by counting how many rhythms you can hear while holding on perhaps a bit more closely to one in particular".

The process described here of absorbing the aggregate pattern whilst paying attention to a particular integrant pattern is clearly an instance of prioritised integrative attending. The traditional learning methods employed by African drum masters ensure that such an attentional strategy is encouraged: "The African learns the whole simultaneously with the parts…" (Pantaleoni & Serwadda, 1968, p. 52). Drummers thus learn to place their entries in relation to the other instrumental parts, rather than in relation to the underlying pulse. In effect, "one rhythm defines another" (Chernoff, p. 52) to the extent that it is more difficult to perform a part alone than in the whole ensemble context. With regard to Westerners' success at learning African drumming, Chernoff (1979, p. 52) claims that "the critical factor which determined a student's progress was not so much his former musical experience as his acquisition of the ability to pay attention to a second rhythm while playing". This indicates that prioritised integrative attending skills are fundamental in realising the goals of multipart interactions in African music.

Of course, the importance of prioritised integrative attending is by no means limited to African music on the world music stage. In a discussion of Indonesian music, Campbell (1991, p. 259) points out that:

> "In the traditional training for performance in the Indonesian gamelan [a large percussion ensemble], the musician must learn all the instruments – from the gongs that provide a rhythmic structure to the fixed melody of the xylophones to the elaborating instruments… This flexibility marks an awareness of the contributions of individual instruments to the musical whole".

### 2.2.2 The musical mind within the musical environment

Anthropological and ethnomusicological descriptions of the spiritual and communicative goals of rhythmic behaviour (e.g., Williams, 1967; Chernoff, 1979) highlight the existence of links between the human mind and the environment in which it is operating. These links are formally delineated in the dynamical approach to cognition, where the notion that the cognitive system is comprised of the nervous system, the body, and the environment is indispensible (Van Gelder & Port, 1995). Indeed, the synergy of mind, body, and environment is considered to be the driving force behind the synchronisation processes (such as attunement) referred to by dynamical models that address musical rhythm perception (e.g., Jones, 1976; Jones & Boltz, 1989; Large & Jones, 1999; Large & Kolen, 1994; McAuley, 1994; Michon, 1985; Port, Cummins, & McAuley, 1995).

Including the environment as an integral component of the musical cognitive system makes unavoidable the recognition of constraints that ensure the optimisation of rhythmic behaviour. Ethnomusicological accounts of African multipart rhythmic behaviour imply that these constraints encourage integrative attending in general. Accordingly, discussions of African music generally recommend an attentional strategy that allows the aggregate pattern to be abstracted from several integrant patterns that occur simultaneously. However, it is acknowledged that under certain circumstances it is necessary that attention be divided between an integrant, and the aggregate aspect. In other words, it is sometimes desirable to focus attention on a single part, or a subset of parts, and allow the remaining parts in the texture to be peripherally attended. These situations are instances of prioritised integrative attending. The circumstances under which this type of strategy is advisable are more fixed for performers than for listeners or dancers, because, for the performer, the integrant patterns that require special attention usually comprise the part they are performing. Hence, optimal behaviour in multipart interactions is easiest to define from the performer's perspective. Musical ensembles provide a readily controlled micro-environment where multipart performance goals can be investigated.

## 2.3 Prioritised integrative attending in ensemble performance

### 2.3.1 Goals of ensemble performance

A universal goal in ensemble performance is the production a unified, cohesive, and coherent musical structure from a collection of distinctive instrumental or vocal parts. These parts are usually differentiated by a number of factors, including timbre (instrumental tone colour), tessitura (pitch range), rhythm, and spatial location. The task faced by ensemble performers is to present these parts in a manner that encourages their integration by the audience: “Ensemble performance may be viewed as a composite that is more than the sum of separate musical parts” (Campbell, 1991, p. 245).

To realise this goal, ensemble performers must simultaneously attend to the part they are playing and the parts played by others. Dividing one’s attentional resources in this way is necessary to facilitate a ‘meaningful interaction’ between each individual performer and the rest of the ensemble: they must be at least in time, in tune, balanced in terms of relative loudness, and in agreement in terms of phrasing and articulation. The behaviour of each performer can be considered to be optimal, or adaptive, to the extent that it contributes to the realisation of this ideal synergy. Hence, prioritised integrative attending should constitute an important component of adaptive behaviour in a majority of ensemble settings.

Evidence that prioritised integrative attending is important to the realisation of the goals of ensemble performance can be gleaned from the testimonials of highly accomplished ensemble musicians. In a monograph written in collaboration with the members of the Guarneri String Quartet, Fink and Merriell (1985, p. 15) advise that “With alert sensitivity to what your part is saying, to what each of the other voices is doing, to what the leader of the moment is inviting you to match, you will lift your performance to a higher level, and in doing so fulfil the incredible potential the string quartet has of transcending the sum of its parts”. Here the emphasis placed upon the need to pay attention to the features of separate parts, as well as to the Gestalt, or whole qualities of the ensemble, implies the enlistment of a priroritised integrative attending strategy.

### 2.3.2 Research on ensembles

Despite opinions of expert ensemble musicians on the importance of prioritised integrative attending, there is scarcely any empirical work devoted specifically to identifying the factors that influence attending in ensemble contexts. Research on music ensembles (see Humphreys, May, & Nelson, 1992, for a review) has usually been conducted within the domain of music education. It has, therefore, focused predominantly upon the factors that motivate school-age individuals to participate in ensembles, and the effects of such participation upon the individual’s general musical aptitude and ability. Although this work on school ensembles does not directly address prioritised integrative attending, its findings do highlight some factors that affect ensemble related behaviour generally.

Factors such as Intelligence Quotient test scores, scores on various music aptitude tests, musical preferences, personality characteristics, and psychomotor skills have been found (to varying degrees and with varying reliability) to play a role in initiating and maintaining ensemble participation (Humphreys et al., 1992). For example, Young (1971) found that dropouts from a fifth-grade ensemble obtained significantly lower scores on a popular musical aptitude test (Gordon's, 1965, *Musical Aptitude Profile*) than those who continued, especially on the rhythm subtest. With regard to the effects of ensemble participation, benefits seem to accrue to musical aptitude, musical achievement, and musical perception and discrimination as a consequence of ensemble experience. Once again, rhythmic abilities are strongly implicated. For example, Heritage (1986) found ensemble experience to be correlated with rhythmic discrimination ability. Likewise, Boisen (1979) found that ensemble experience and ability to perceive complete rhythmic patterns were related. Of course, causal relationships can not be established on the basis of this research due to its correlational nature. Indeed, although the research described above points to benefits in ensemble due to rhythmic ability, Radocy and Boyle (1988, p. 117) claim that the reciprocal is also true: "Ensemble experience is one method of making students conform to the underlying beat". Nevertheless, the relationships identified above, such as that between rhythmic abilities and ensemble participation, invite examination by experimental manipulations.

### 2.3.3 Fostering prioritised integrative attending in ensembles

Contributions that are perhaps more directly relevant to prioritised integrative attending can be found in descriptions by practising music educators of rehearsal techniques that appear to encourage this mode of attention. A compilation of such techniques by Casey (1991) is summarised in Table 2.1. The listening strategies prescribed by these techniques vary in sophistication. The technique of 'visualising the total ensemble sound' (rehearsal technique 6), which involves forming 'images' of both vertical and horizontal aspects of the desired ensemble sound, may be considered relatively sophisticated. A proponent of this strategy describes it as a "holistic concept that removes individual's interpretation of his own sound, so all of his attention is being directed to the total ensemble sound" (contribution by Lisk, in Casey, 1991, p. 298). On the other hand, some music educators recommend less specific strategies, such as simply 'reminding ensemble performers to listen' to each other (rehearsal technique 9): "I get off the podium and click my fingers four pulses when they're not synchronised. I say, 'You're not listening to each other' " (contribution by Suddendorf, in

Casey, 1991, p. 301). This latter approach is less sophisticated in the sense that it does not provide information about precisely what to listen for.

A unifying feature of the more sophisticated rehearsal techniques is that they attempt to encourage the ensemble members to adopt specific listening strategies that enable attention to be targeted efficiently. To varying degrees, they provide explicit or implicit guidelines about how to listen, and for what to listen. Some further techniques that are applicable to particular types of ensembles have been described by Campbell (1991). For example, for choirs she recommends a rhythmic chant activity that is intended to "reinforce the problem part [i.e., the high priority part] in relationship to other voice parts" by requiring "the full ensemble to chant the entire piece rhythmically, allowing its overlapping texts and polyphonic textures to be made clear" (Campbell, 1991, p. 266). Campbell goes on to add that "In addition to learning the rhythmic complexities of a work, articulation and an awareness of texture can be developed through the [rhythmic chant] experience" (p. 266).

Although there is considerable anecdotal evidence that these techniques facilitate the achievement of the goals of ensemble performance, explanations of their effectiveness (when offered) are purely speculative. Gaining a better understanding of prioritised integrative attending would be beneficial to the eventual development of a system of progressive techniques designed to foster optimal ensemble performance, in addition to benefits in developing theories of rhythm and attention in general. In order to achieve such an understanding it is necessary to identify the factors, both *musical* (i.e., pertaining to characteristics of the music) and *extramusical* (i.e., pertaining to characteristics of the performer or the performance environment), that influence ability to engage in prioritised integrative attending. In addition to identifying musical and extramusical factors, it is necessary to understand the nature of the relationship between these factors and prioritised integrative attending.

**Table 2.1:** Rehearsal techniques for encouraging integrative attending in ensembles.

| Technique | Explanation of effectiveness |
|---|---|
| (1) eliminating visual contact between ensemble members by instructing them to either close their eyes or turn their backs to each other | *increases aural awareness* |
| (2) rotating the seating within a section of the ensemble | *encourages familiarity with the parts played by others* |
| (3) varying (either systematically or randomly) the seating in the ensemble | *causes the music to be heard from a different perspective* |
| (4) encouraging participation in small ensembles | *increases the sense of responsibility in individual members; reduces amount of information to process; makes individual parts easier to hear; reduces physical distance between performers* |
| (5) playing without the conductor | *creates demands similar to those in small ensembles; develops a sense of internal pulse* |
| (6) 'visualising' the total ensemble sound | *directs attention to the total ensemble sound* |
| (7) utilising the "trio concept", where each ensemble member listens specifically to their immediate (left and right) neighbours, rather than to the group as a whole | *provides a very specific, well defined, listening strategy that informs the ensemble members about what to listen to* |
| (8) identifying who the ensemble members should be listening to for the pulse | *provides precise guidelines for targeting attention* |
| (9) reminding ensemble members to listen | *increases aural awareness* |

## 2.3.4 Factors that influence prioritised integrative attending

### 2.3.4.1 Musical factors: Rhythmic, pitch-related, and textural complexity

#### *2.3.4.1.1 Musical factors and attention*

Fortunately, given the relative paucity of research specifically on attending to the multipart textures, the results of research on how various musical factors affect attending to singlepart textures are rich in their implications for understanding prioritised integrative attending.

Some factors that have been found to influence attention in singlepart contexts are (a) *rhythmic complexity* (e.g., Bharucha & Pryor, 1986; Boltz, 1989; Essens, 1995; Essens & Povel, 1985; Franks & Canic, 1991; Handel, 1973; Handel, 1992; Jones & Boltz, 1989; Povel & Essens, 1985; Sturges & Martin, 1974), (b) pitch-related factors such as the *size of the intervals between adjacent pitches* and *melodic contour* (e.g., Dowling, 1978; Dowling & Bartlett, 1981; Dowling, Kwak, & Andrews, 1995; Idson & Massaro, 1978), and (c) *tonality or harmonic context* (e.g., Dawe, Platt, & Racine, 1993; Holleran, Jones, & Butler, 1995; Krumhansl, Sandell, & Sargeant, 1987; Palmer & Krumhansl, 1987; Schmuckler, 1989; Smith & Cuddy, 1989). The common theme is all of these factors appears to be that as complexity increases, attending becomes less efficient and less flexible.

It was argued in Chapter 1 that the approach that most readily lends itself to the task of explaining prioritised integrative attending in ensemble contexts is Jones' (e.g., Jones, 1976; Jones & Boltz, 1989) theory of dynamic attending. The dynamic attending approach proposes that processing efficiency and attentional flexibility are facilitated by the formation of temporal expectancy schemes based on attunements. A correspondence has been identified between these schemes and rhythm-related mechanisms such as metric frameworks (see 1.2.3.2.2). However, expectancy schemes are also influenced by 'motion-like relations' that emerge through patterns of pitch and intensity change (Jones & Yee, 1993). The pitch-based expectancies follow trajectories that are defined by tonal and harmonic relationships that come to exist within a listener's mental pitch space through "both inherent attentional biases and experience with a culture's music" (Jones, 1990, p. 224). The extent to which space-time expectancies based on attunements and motion-like relations are violated affects attentional flexibility (Jones & Yee, 1993). It follows that complexity in terms of rhythm and pitch-related factors should affect the progress of prioritised integrative attending in ensemble contexts.

#### *2.3.4.1.2 Rhythmic and pitch-related factors*

Rhythmic complexity may affect prioritised integrative attending directly through its effects upon the process of attunement described in the dynamic attending approach (Jones, 1976; Jones & Boltz, 1989). Specifically, when the attunement process is disrupted by rhythmic complexity, attempts to re-establish a basis for synchronisation may divert attention away from the task of scanning other parts with a view to integrating them with the part that one is performing. The rhythmic complexity of both (a) an individual's part (i.e., an individual integrant pattern), and (b) the relationship between this part and other parts, might be particularly influential in this regard. The emphasis placed by the dynamic attending approach upon the rhythmic basis of attunement implies that complexity in terms of rhythm may be the *principal* factor that affects prioritised integrative attending. The importance of rhythmic factors is also suggested by Rasch's (1988, p. 81) observation that asynchronies between ensemble parts are caused by "uncertainty concerning the temporal structure". More specifically, he notes that this uncertainty is commonly associated with "ritenuto or accelerando sections" and "sections that are complicated with regard to rhythm and/or metre" (Rasch, 1988, p. 81).

The effects of pitch-related factors such as pitch interval size and melodic contour that operate at the level of individual integrant patterns upon prioritised integrative attending have not been directly investigated. Nevertheless, predictions about the relationship between these pitch-related factors and prioritised integrative attending can be derived from the dynamic attending approach, and also from other approaches that emphasise expectancy formation (e.g., Narmour's, 1990, 1992, 'implication-realization' model). Such approaches assume that attentional demands become greater with increasing size of the interval between adjacent pitches and increasing 'jaggedness' of melodic contour (where many reversals in the direction of pitch change occur during a short period of time, or the direction of pitch change is difficult to predict on the basis of preceding intervals). It follows that small pitch intervals and smooth melodic contours more readily afford the attentional flexibility necessary for prioritised integrative attending, and that there are attentional biases that constrain expectancy formation in favour of slow rates of pitch change. Work on auditory streaming is consistent with these notions (Bregman, 1990; van Noorden, 1975; ten Hoopen, 1996).

Ability to engage in prioritised integrative attending is presumably also affected by pitch-related factors, such as tonality and harmonic context, which operate on a larger scale than pitch interval size and melodic contour. Several sets of experimental findings suggest that tonal and harmonic contexts that are familiar to a listener allow attention to be targeted efficiently. For instance, 'goodness-of-fit' ratings of 'probe tones' presented after brief exposure to a tonal or harmonic context are influenced by whether the preceding context is familiar or unfamiliar (Krumhansl & Shepard, 1979; Krumhansl et al., 1987). Furthermore, familiar tonal and harmonic contexts facilitate the detection of pitch changes (e.g., Holleran et al., 1995; Smith & Cuddy, 1989). These findings invite the proposal that idiomatically familiar tonalities and harmonic contexts facilitate prioritised integrative attending.

The effects of rhythm and some pitch-related factors upon prioritised integrative attending can be seen in experimental work on the auditory streaming and polyrhythmic patterns (sees 1.2.2.4 and 1.2.3.2.2). Investigations of auditory streaming typically focus upon the effects of pitch separation and presentation rate upon the tendency for sequences of high and low tones to stream. Jones and Yee (1993, p. 80) conclude from this work that "Patterns with large frequency velocities [i.e., fast rates of pitch change]… hamper full attentional synchronicity and so constrain integrative attending".[6] However, rhythmic factors also affect the tendency to segregate or integrate sequences. Jones et al. (1981) found that rhythmic structure in fact overrode the influence of pitch-based grouping tendencies upon streaming. This research is particularly significant in that it highlight the benefits of employing a (nonprioritised) integrative attending strategy in certain tasks related to the perception and production of multipart patterns. Similar findings have emerged from studies that address the perception and production of polyrhythms. After reviewing relevant studies, Jones and Yee (1993, p. 90) conclude that "people can effectively 'divide' their attention among different sequences when these are integrated into a single scheme". Monahan and Carterette (1985) have also found primacy of rhythm over pitch in listeners' responses to musical patterns.

#### *2.3.4.1.3 Textural factors*

*Textural density* is related to the number of parts in the ensemble, and how differentiated they are in terms of rhythm, tessitura, and timbre. The existence of a relationship between prioritised integrative attending and textural density is suggested by empirical research into performance on divided attention tasks, plus more anecdotal evidence and musical intuition. This relationship may be causally associated with considerations such as the amount of information from different sources that require simultaneous attention. Work on divided attention (e.g., Wickens, 1980, 1984, 1991; Smyth et al., 1987) suggests that performance decrements are associated with increasing number, and complexity of information sources that are monitored. Therefore, prioritised integrative attending should be more difficult to engage when the texture is 'dense' (e.g., where there are many parts that are highly differentiated), than when it is relatively 'transparent' (e.g., where there are few parts, and these parts are not highly differentiated). The existence of several rehearsal techniques that involve reducing the size of the ensemble (e.g., rehearsal techniques 4 and 7 in Table 2.1) supports this proposal. Related research has been conducted by Huron (1989), who found

[6] Jones and Yee (1993) refer exclusively to nonprioritised integrative attending.

that identifying the entry of voices in polyphonic music was made more difficult by increasing number of voices.

The relationship proposed here between textural density and prioritised integrative attending may influence the ability of ensemble performers to play in synchrony. Rasch (1988) reports that the standard deviation of onset asynchronies becomes larger when the number of performers in an ensemble increases. Introducing a conductor to the ensemble typically attenuates this trend. However, Rasch found that if a conductor is used by an ensemble consisting of less than nine performers, asynchrony actually increases! This may indicate that the presence of a conductor encourages performers to rely upon visual cues provided by the conductor's gestures, rather than their own prioritised integrative attending capabilities, to find the 'beat'.

The *textural role* of the part played by an ensemble member (e.g., lead or accompanimental) may also be considered as a relevant textural factor. Performance conventions seem to indicate that those performing accompanimental parts are required to be more responsive, and hence more attentive, to lead parts than the reverse. Thus, the orchestra is expected to follow the spontaneous tempo variations introduced by the soloist in a concerto, as well as holding responsibility for maintaining suitable balance in terms of relative loudness. The conductor, of course, attempts to assist these processes. This implies that prioritised integrative attending may be encouraged to a greater extent when accompanying, than when leading. More importantly, however, performing a lead role may make greater demands upon attentional resources than performing accompanimental parts, as lead parts are typically more complex than accompanimental parts in terms of the musical factors discussed above (rhythm; pitch interval size; melodic contour). The relatively high attentional demands associated with performing lead parts may, in some cases, preclude the requisite flexibility for prioritised integrative attending.

#### 2.3.4.2 Extramusical factors: Arousal, anxiety, and technical mastery

The contribution of personality characteristics and psychomotor skills as moderate predictors of success in school ensembles (section 2.3.2) suggests a role for extramusical factors such as arousal, anxiety, and technical mastery. It is believed that there is an optimum range of *arousal* levels for performing tasks with cognitive and motor skill components. Excessively low or high levels of arousal (as caused by fatigue due to sleep loss and intense physical exertion, respectively) impair performance on such tasks by altering both the way in which attentional resources are allocated and the speed with which psychomotor processes are executed (e.g., Davey, 1973; Ryman, Naitoh, & Englund, 1985).

With regard to performance *anxiety*, Salmon and Meyer (1992) argue that managing anxiety cues during performance demands a significant portion of the musician's limited attentional resources, thereby diminishing the amount of attention available for interpretive activity or other performance-related tasks. Such anxiety cues may be especially salient when performing lead, as opposed to accompanimental, parts due to both greater technical complexity and demands or expectations from others (see Gabrielsson, 1999). Finally, the degree to which a performer has achieved the level of *technical mastery* that is required to perform a part may affect ability to simultaneously pay attention to other parts. Thus, prioritised integrative attending is perhaps hampered by technical demands if these claim a large portion of attentional resources.

#### 2.3.4.3 Automaticity and the development of prioritised integrative attending skills

The notion that attentional efficiency and flexibility are requisites for prioritised integrative attending raises questions about the degree to which prioritised integrative attending can proceed automatically, and whether this skill improves more markedly with specific practice or with ensemble playing generally. Although research on implicit auditory memory (see Church & Schachter, 1994; Crowder, 1993a) suggests that some features, such as pitch interval size and contour, of the parts played by others in an ensemble may be processed automatically or preattentively, studies conducted by Zacks, Hasher, Alba, Sanft, and Rose (1984) and Jackson (1985) indicate that processing purely temporal information requires focused attention. This suggests that, whereas some aspects of the task faced by ensemble performers (e.g., maintaining balance and intonation) may be accomplished automatically, the prioritised integrative attending that is necessary for maintaining rhythmic cohesion and uniformity of phrasing, articulation, and expressive timing (e.g., rubato) across the parts in the ensemble requires the expenditure of attentional effort by the performer. Finally, with regard to the development of prioritised integrative attending skills, the apparent efficacy of the various rehearsal techniques implies that specific practice at prioritised integrative attending is most beneficial. Nevertheless, the fact that some techniques involve simply reducing the size of the ensemble suggests that certain experiences encountered in the context of small ensembles may lead naturally to improvements in ability to engage in prioritised integrative attending.

#### 2.3.4.4 Summary

The evidence reviewed above suggests that, in order to achieve the goals of ensemble performance, a prioritised integrative attending strategy is generally most beneficial. Various rehearsal techniques have emerged in the music education system that apparently foster prioritised integrative attending. Research on school music ensembles and theoretical approaches that address attending to auditory events implicate some musical factors such as rhythmic complexity, pitch interval size, melodic contour, textural density, and textural role. Although the relative degree to which these factors influence prioritised integrative attending in ensemble contexts has not yet been incorporated into a descriptive or theoretical framework, the emphasis placed by the dynamic attending approach (Jones, 1976, Jones & Boltz, 1989) upon temporal aspects of events suggests that rhythmic complexity is perhaps the most influential. The relationship between rhythmic abilities and achievement in ensembles identified by research on school ensembles, and the existence of rehearsal techniques that involve focusing upon the musical pulse or beat, are consistent with this suggestion. Other work suggests that extramusical factors, such as arousal, anxiety, and mastery of the technique required to perform a part also affect prioritised integrative attending. Here, the relative importance of these musical and extramusical factors, as well as issues concerning the automaticity and development of prioritised integrative attending skills, are examined in an exploratory survey-based study. This study serves a dual role in explicating the issues discussed in this chapter and providing the groundwork for the experimental studies in later chapters.

## 2.4 The Ensemble Performance Questionnaire (EPQ)

### 2.4.1 Aims of the EPQ

The Ensemble Performance Questionnaire (EPQ) was developed as a tool for gathering information related to musicians' introspections about prioritised integrative attending in musical ensembles. Specifically, the EPQ was designed to elicit the opinions of practising ensemble musicians regarding (a) the perceived importance of prioritised integrative attending in ensemble performance and (b) the degree to which various musical and extramusical factors influence ability to engage in prioritised integrative attending.

## 2.4.2 Method

### 2.4.2.1 Questionnaire items

A copy of the EPQ appears in Appendix 2.1. The EPQ consists of 10 questions that relate to factors that could potentially influence prioritised integrative attending. The first four of these questions address demographic details (e.g., age; gender) and musical experience (e.g., instrument/s played; number of years each instrument played; types of ensembles regularly performed in; total number of years in ensembles). Question 5 addresses the perceived importance of prioritised integrative attending in ensemble performance. Respondents are asked to rate how *important* it is to simultaneously pay attention to one's own part and the parts played by others, on a 4-point scale (1 = "not very important"; 4 = "of utmost importance"). An open-ended sub-question asks participants to justify their rating.

Questions 6 to 8 address the influence of various musical and extramusical factors upon prioritised integrative attending. Question 6 has several items, each asking about the level of influence of a particular musical factor. The musical factors considered are *rhythmic complexity*, the pitch-related factors *pitch interval size*, *melodic contour*, and *tonality or harmonic context*, and the textural factors *textural density* and *textural role*. The effects of rhythmic complexity are considered from three perspectives: when related to one's *own* part, when related to *other* parts, and when related to the relationship between one's own part and other parts (i.e., *overall* complexity). Similarly, pitch interval size and melodic contour are considered from the perspective of both one's *own* part and *other* parts. For each item, level of influence is rated on a 4-point scale (1 = "not at all influential"; 4 = "very influential"). Respondents are also asked to list any additional musical factors that they feel are influential. Question 7 asks about the level of influence of extramusical factors (*arousal*; *anxiety*; *mastery of technique*) upon prioritised integrative attending. Once again, level of influence is rated on a 4-point scale, and respondents have the opportunity to list additional extramusical factors. Question 8 contains two open-ended questions. In one, respondents are asked to describe situations that necessitate focusing attention 'inward' to one's own part, and the other asks about situations that encouraged attention to be focussed 'outward' to other parts.

Question 9 addresses the degree to which prioritised integrative attending can proceed automatically. Respondents are asked to indicate how often (always; sometimes; never) they have to concentrate on thinking about simultaneously paying attention to their own part and other parts. They are also asked to comment their response. Finally, in Question 10, respondents are asked about whether, in their experience, prioritised integrative attending skills improve with practice, and if so, whether this practice needs to be geared specifically towards improving these skills, or if they improve with ensemble playing generally.

#### 2.4.2.2 Respondents

The musicians surveyed varied in terms of musical experience or 'status'. Respondents were 24 professional orchestral musicians (4 females and 20 males), 53 amateur orchestral musicians (30 females and 23 males), and 35 jazz musicians or improvisers (13 females and 22 males) (N = 112, which represents a 50% response rate). The sample size varied slightly for different questions in the EPQ because not all respondents completed each question in full. Median age was 30 years for professionals, 22 years for amateurs, and 25 years for improvisers. All musicians had experience playing in small instrumental ensembles. Average experience in ensembles was 18 years for professionals, 11 years for amateurs, and 9 years for improvisers. The major instrumental families typically employed in the performance of Western music (i.e., string, woodwind, brass, and percussion) were represented in each group.

#### 2.4.2.3 Procedure

The EPQ was distributed to professional orchestral musicians by their orchestral managers. Questionnaires were distributed to amateur orchestral musicians by their conductors. An improvisation lecturer at a performing arts college distributed questionnaires to jazz musicians. The people responsible for distributing the EPQ were not required to give any special instructions to respondents. All instructions were contained in the questionnaire.

The EPQ took approximately 30 minutes to complete. Respondents returned completed questionnaires individually by mail in provided 'reply paid' envelopes.

### 2.4.3 Results

#### 2.4.3.1 The importance of prioritised integrative attending

##### *2.4.3.1.1 Importance ratings*

Respondents' ratings (in Question 5a) of the importance of simultaneously paying attention to one's own part and other parts (see Appendix 2.2) indicated that musicians of varying status, on average, believe prioritised integrative attending to be between "very important" and "of utmost importance" (mean rating on 4-point scale = 3.6). However, an analysis of variance (ANOVA – see Appendix 2.3) revealed that perceived importance did vary according to status. In this analysis, post-hoc contrasts were tested using the Scheffe procedure. Alpha was set at .05 and the critical value for $F(2,109)$ is 6.3.

The results of this analysis indicate that the ratings produced by professional orchestral musicians and jazz musicians are significantly higher than those produced by amateur orchestral musicians – $F(2,109) = 9.82$ and $F(2,109) = 10.62$, respectively – but do not differ significantly from each other (see Figure 2.2). This suggests that prioritised integrative attending in ensemble contexts is believed to be more important by professional orchestral and jazz musicians, than by amateur orchestral musicians.

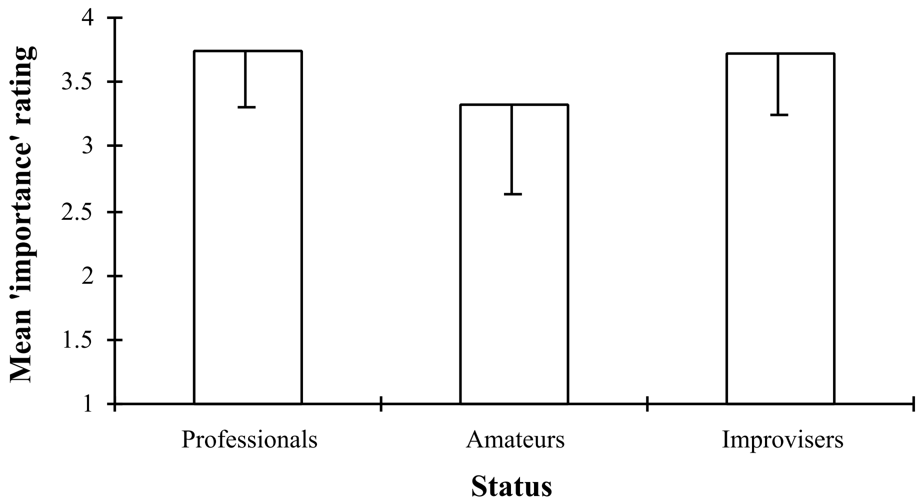


**Figure 2.2:** Ratings by musicians of importance of prioritised integrative attending.

Perhaps the difference in perceived importance of prioritised integrative attending can be explained by a greater degree of independence from musical scripts (i.e., scores) in professionals and improvisers than in amateurs. Professionals ideally rehearse a part thoroughly before a performance, and hence should not need to invest as much effort into its interpretation during performance. Further, sight-reading – the process of translating a script's directions into the prescribed sounds – is more likely to proceed automatically in professionals than in amateurs. In short, for amateurs, the combination of reading a script and executing the prescribed techniques may be sufficiently demanding to interfere with the process of directing attention to what others are doing. Improvisers are rarely faced with this problem, as they typically do not rely on written scripts at all for performance. More importantly, they must listen to others in order to produce improvisations that complement other parts.

#### *2.4.3.1.2 Respondents' comments*

Comments made by musicians (in Question 5b) from all status groups in justification of their ratings of the importance of simultaneously paying attention to one's own part and other parts (see Appendix 2.2), were entirely consistent with the proposal that prioritised integrative attending is necessary for the realisation of the goals of ensemble performance. Nevertheless, there were some characteristics that distinguished comments made by musicians of different status. These differences became apparent when comments were classified according to the whether ensemble goals were general or specific (goal specificity), and then within the specific category, whether goals were fundamental or expressive (goal sophistication). With regard to goal specificity, goals were classified as specific only if they identified particular aspects of the ensemble sound (e.g., balance, intonation, phrasing, articulation, and rhythmic cohesion). With regard to goal sophistication, expressive goals that allow a performance to transcend mere mechanical accuracy (e.g., phrasing, articulation, and rhythmic cohesion) were considered to be more sophisticated than fundamental goals (e.g., balance and intonation).

After comments were classified, a Chi-square analysis was conducted. The results of this analysis indicate that professional and amateur orchestral musicians were the most likely to explicitly mention the impact of prioritised integrative attending upon realising specific goals in ensemble performance, whereas improvisers tended to describe general goals: $\chi^2(df=2) = 15.2$ (for $df=2$, the critical value for $\chi^2_{.05}$ is 5.99) (see Figure 2.3 & Appendix 2.4). For instance, orchestral musicians typically listed features of the ensemble sound that are affected by ability to engage in prioritised integrative attending, such as balance, intonation, tempo, rhythmic cohesion, pitch stability, expressive timing, phrasing, articulation, stylistic elements, and tone colour. On the other hand, comments by improvisers stressed the importance of prioritised integrative attending for producing a generally coherent and unified ensemble sound. Additionally, improvisers' comments frequently reflected the unique demands of their genre, wherein performances are usually unscripted. Accordingly, improvisers emphasised the importance of musical communication, or interaction between ensemble members, as a concomitant of prioritised integrative attending. In particular, they highlighted its role in guiding the creative processes involved in improvisation towards the formation of coherent musical structures. As one improviser said "…it is the spontaneous reaction of all ensemble members to the total ensemble sound which is the mechanism of coherence and listenability/liveliness".

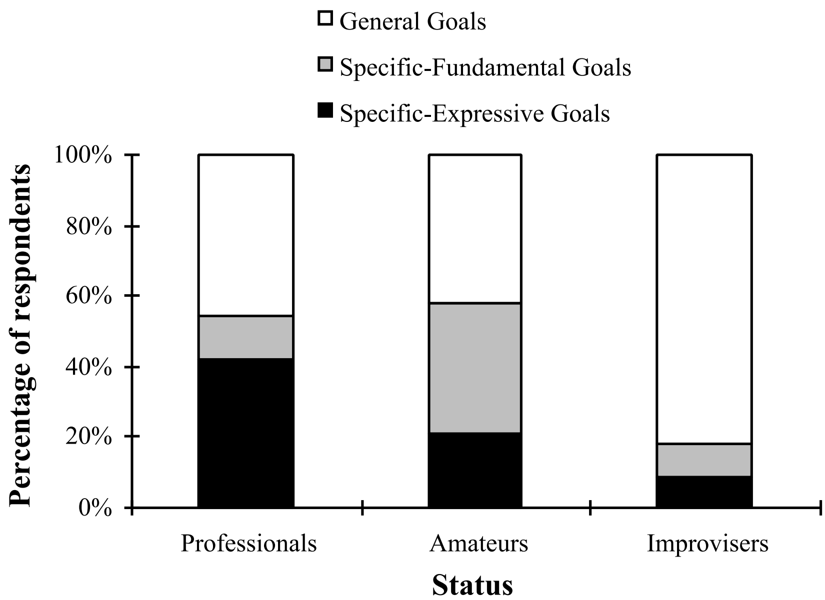


**Figure 2.3:** Percentage of respondents' comments that refer to general versus specific (fundamental or expressive) goals of ensemble performance.

Although professionals and amateurs both commented upon the importance of prioritised integrative attending for achieving specific goals in ensemble performance, amateurs were less likely than professionals to go beyond listing fundamental goals concerning coherence in terms of balance, intonation, and tempo: $\chi^2(df=1) = 5.88$ (for $df=1$, the critical value for $\chi^2_{.05}$ is 3.84) (see Figure 2.3 & Appendix 2.4). This suggests (consistently with the 'importance' ratings discussed earlier) that amateurs perhaps have a less sophisticated conception of role of prioritised integrative attending than professionals: the former acknowledge its function in achieving a 'mechanical' sense of ensemble cohesion (e.g., staying in time and in tune), whereas the latter also consider its facilitation of a more 'expressive' coherence.

Finally, comments by professionals emphasised the role of prioritised integrative attending in facilitating rhythmic coherence. In comments mentioning the specific goals of prioritised integrative attending, rhythmic coherence was referred to more often than any other factor, apart from the elementary goals of coherence in terms of balance, intonation, and tempo.

Rhythmic coherence was mentioned by approximately 23% of professionals, whereas other factors were mentioned, on average, by only 6%: $\chi^2(df=1) = 5.85$ (see Appendix 2.4). Comments that addressed rhythm typically stressed the importance of the integrity of the rhythmic relationship between separate parts in the ensemble: e.g., "It is not enough to merely count, or follow a conductor when playing in a group. [One] Must listen to others so that parts are interpreted consistently. Rhythmically, it is very important to be aware of other parts to fit the different parts together".

### 2.4.3.2 Factors that influence prioritised integrative attending

#### *2.4.3.2.1 Level of influence ratings*

An ANOVA was carried out on musicians' ratings of the level of influence upon prioritised integrative attending of the various musical and extramusical factors listed in Questions 6 and 7 (Appendices 2.5 & 2.6). In this analysis, post-hoc contrasts were used to compare ratings produced for musical factors with those produced for extramusical factors. In addition, comparisons were made between ratings produced for individual musical factors (rhythmic complexity; pitch interval size; melodic contour; tonality or harmonic context; textural role; textural density) and individual extramusical factors (arousal; anxiety; mastery of technique). The locus (own part; other parts; relationship between parts) of the rhythmic complexity, pitch interval size, and melodic contour factors, was also considered in the analysis. Alpha was set at .05, and the Scheffe adjusted critical value for $F(2,104)$ is 6.3.

When musical and extramusical factors were compared, it was found that extramusical factors received significantly higher ratings, on average, than musical factors, $F(2,104) = 49.3$ (see Figure 2.4). This suggests that musicians believe that their ability to engage in prioritised integrative attending is affected to a greater extent by extramusical factors than by musical factors.

Within the extramusical factors, comparisons revealed that level of influence ratings were higher for arousal and technical mastery than for anxiety ($F(2,104) = 10.37$ and $F(2,104) = 25.25$, respectively), but did not differ significantly from each other (see Figure 2.4). This suggests that anxiety is perceived to affect prioritised integrative attending to a lesser degree than arousal and mastery of technique. Strategies for managing anxiety are probably more readily available and can be implemented more conveniently than methods for altering one's state of arousal or improving one's technique.

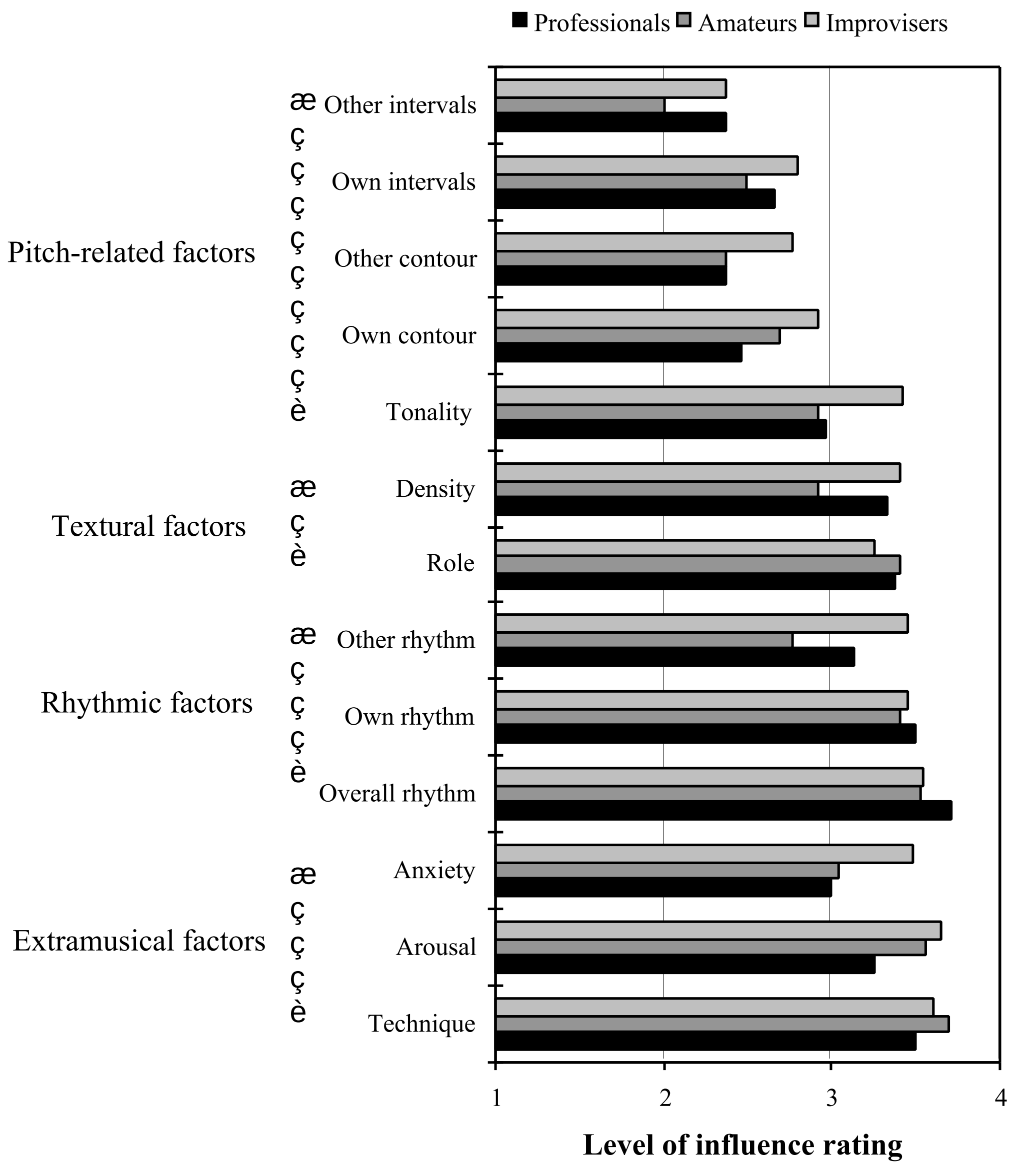


**Figure 2.4:** Mean level of influence ratings for extramusical and musical factors.

When individual musical factors were considered in the analysis, it was found that: (a) rhythmic complexity received higher level of influence ratings than pitch-related ($F(2,104) = 120.97$) and textural ($F(2,104) = 7.28$) factors; (b) textural factors received higher ratings than pitch-related factors ($F(2,104) = 93.26$); (c) within the category of pitch-related factors, tonality (and harmonic context) received higher ratings than both pitch interval size and melodic contour ($F(2,104) = 37.21$ and $F(2,104) = 31.89$, respectively), but the difference between ratings for melodic contour and pitch interval size was not significant; (d) the ratings produced for textural density did not differ significantly from those for textural role (see Figure 2.4). These findings basically indicate that ensemble musicians believe that their ability to engage in prioritised integrative attending is affected to the greatest extent by rhythmic complexity. Textural factors, such as textural density and textural role, are believed to exert the next most amount of influence upon prioritised integrative attending, followed by pitch-related factors. Amongst pitch-related factors, tonality is believed to be most influential, followed by melodic contour and pitch interval size.

Generally, musical factors that impact upon the performer's own part received higher level of influence ratings than factors impacting upon other parts, $F(2,104) = 20.01$ (see Figure 2.4). As might be expected intuitively, ability to engage in prioritised integrative attending is interfered with to a greater extent by complexity in one's own part than by complexity in other parts.

In the case of rhythmic factors, the complexity of one's own part and overall complexity (i.e., the complexity of the relationship between one's own part and other parts) received higher ratings than the complexity of other parts, $F(2,104) = 12.85$ and $F(2,104) = 37.55$, respectively (see Figure 2.4). However, no significant differences were detected when level of influence ratings for the complexity of one's own part and overall complexity were compared. These results seem to suggest that the rhythmic features of other parts affect ability to engage in prioritised integrative attending only to the extent that they influence the rhythmic interpretation of one's own part.

With regard to the effects of the musicians' status on the perceived influence of rhythmic factors, the difference in the level of influence of the complexity of one's own part and the complexity of other parts was larger in ratings produced by amateur orchestral musicians than in ratings produced by improvisers, $F(2,104) = 9.25$. Likewise, the difference between ratings produced for the complexity of other parts and overall complexity was more pronounced in amateur orchestral musicians than in improvisers, $F(2,104) = 15.67$. No other interactions of musical status ans these factors were significant. These findings may reflect greater reliance upon other parts in the ensemble for musical ideas by improvisers than by amateur orchestral musicians

#### *2.4.3.2.2 Respondents' comments*

Musicians' responses to the questions asking them to describe situations that demand more attention to be focused upon either their own part (Question 8a), or other parts (Question 8b) (see Appendix 2.7), generally confirm the notion that prioritised integrative attending is discouraged by increasing complexity in terms of the rhythmic, pitch-related, and textural factors surveyed in the EPQ. Interestingly, with respect to textural density, some musicians mentioned that prioritised integrative attending is a more realistic ideal in small ensembles. In addition to the listed factors, respondents suggested that the following influence ability to engage in prioritised integrative attending: (a) overall loudness, (b) balance, (c) frequency of meter change in mixed meter music, (d) instrumentation, (e) stylistic genre, (f) tempo, (g) intonation, (h) pitch stability, and (i) the type of articulation required. These additional factors apparently affect prioritised integrative attending in a similar manner to the listed factors. For example, the engagement of a prioritised integrative attending strategy was reported to be more difficult at extremely high loudness levels, when the ensemble is not well balanced (in terms of the relative loudness of different instruments), when meter changes frequently, and at excessively fast tempi.

Although the relations between the various musical factors and prioritised integrative attending were generally described as being fairly clear, some intricacies were evident in the case of rhythmic complexity. In particular, musicians' comments revealed an interesting dichotomy in the relation between rhythmic complexity and prioritised integrative attending: complexity in one's own part may either encourage or discourage prioritised integrative attending, depending upon the complexity of the relationship between parts. This dichotomy perhaps exists because, under some circumstances, the complexity of one's own part can be reduced by considering it within the context defined by other parts (e.g., in some elaborate syncopated or hemiola passages). However, under another set of circumstances, the temporal structure of other parts may conflict with one's own part and hence prove to be distracting (e.g., polymetric passages, where separate parts best fit different metric frameworks). In this way, the relationship between parts becomes an influential factor.

If the relationship between parts is rhythmically complex, prioritised integrative attending is discouraged. Accordingly, one professional orchestral musician claimed to focus more attention on his own part "if it is extremely rhythmically complex and doesn't appear to have any relationship to anyone else's part". However, coherent relationships between parts encourage prioritised integrative attending: one amateur orchestral musicians stated that "if the rhythm in my part is difficult, I try to listen to others so that I can catch the main beats". Another amateur claims to focus more attention on other parts when confronted with "difficult rhythms – syncopation", or when "other parts mesh (particularly in modern pieces where the whole is greater than the parts)". The tendency to employ a prioritised integrative attending strategy in such situations is reminiscent of the findings of research on polyrhythmic production (e.g., Deutsch, 1983; Summers et al., 1993), and complements the work by Jones et al. (1995) on selective and nonprioritised integrative attending.

Finally, with regard to extramusical factors, musicians' comments frequently mentioned the effects upon prioritised integrative attending of those factors listed in the EPQ, as well as additional factors. Additional extramusical factors included (a) the reverberation characteristics of the performance venue, (b) the degree to which performance conditions (e.g., lighting, seating, and temperature) are comfortable, (c) physical position relative to other ensemble members, (d) familiarity with the music, (e) competence of other ensemble members, especially soloists, and (f) social considerations such as personal relationships between ensemble members. Generally, comments indicated that circumstances that are either potentially distracting (e.g., high levels of arousal; a performance environment that is uncomfortable or has poor acoustic conditions) or attentionally demanding (e.g., inadequate level of technical mastery; unfamiliar music) hinder prioritised integrative attending.

#### 2.4.3.3 Automaticity and development of integrative attending

Musicians' responses to Question 9, concerning how often they had to concentrate on thinking about simultaneously paying attention to their own part and other parts (see Appendix 2.8), suggest that prioritised integrative attending typically does not proceed automatically. Most professional orchestral musicians (63%) indicated that, in order to adopt this mode of attention, concentration is "always" required. Although less amateur orchestral musicians (40%) felt that concentration was necessary in all situations, most conceded that it was "sometimes" required. Jazz musicians were intermediate in their opinions, with approximately half (49%) of the respondents from this group claiming that concentration was required under all circumstances. Relatively few respondents each from group indicated that concentration was "never" required (see Figure 2.5).

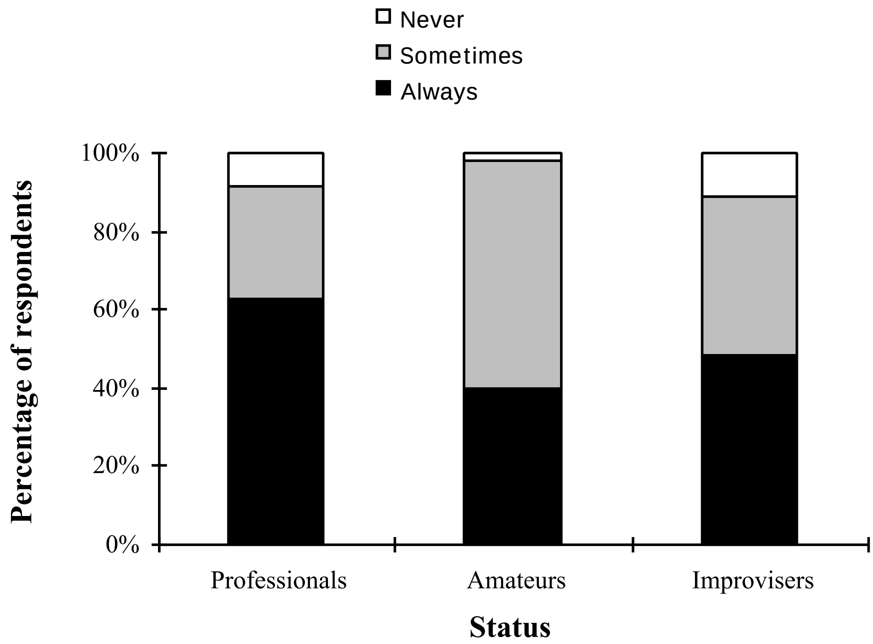


**Figure 2.5:** Percentage of musicians who indicated the need to concentrate upon prioritised integrative attention always, sometimes, or never.

Another way of viewing these results is in terms of the modal (i.e., most frequent) response categories selected by musicians of different status: the modal response for both professionals and improvisers was that concentration is always required for prioritised integrative attending, whereas the modal response for amateurs was that concentration is only sometimes required. Responses to the open-ended sub-questions suggest that this apparent difference in attitude is due mainly to amateurs being more inclined to believe that the need for concentration is related to the complexity and familiarity of their own part. According to this viewpoint, concentration is not required when demands associated with performing a part are low and/or the part is sufficiently familiar. Some amateurs volunteered that prioritised integrative attending was an “automatic process” under such circumstances.

On the other hand, comments by professionals, and improvisers to a lesser extent, tended to reflect the belief that demands associated with achieving an ideal ensemble sound are instrumental in determining the need for concentration upon prioritised integrative attending. Some even provided a checklist documenting aspects of the ensemble sound that are necessary to be monitored during performance: “Check for: rhythmic pulse; pitch stability; intonation relativity; dynamic relativity; articulation similarity; beginnings and endings of notes in relation to others”. However, others did hint at an element of automaticity by stressing that merely an awareness of the relationship between parts, rather than intense concentration, is required: “It isn’t a case of actively thinking or analysing. It’s more a conscious ‘sensing’ of what the other parts are about to do”.

With regard to the development of prioritised integrative attending skills (Question 10), all but one respondent (a jazz vocalist/pianist) agreed that ability to simultaneously pay attention to one’s own parts and other parts improves with practice. More specifically, most musicians in each status group claimed that this skill can be developed through ensemble playing generally, rather than exclusively through practice techniques aimed specifically at improving prioritised integrative attending - $\chi^2(df=1) = 65.1$ (see Figure 2.6 & Appendix 2.9). There were no significant differences due to status. Although these findings suggest that prioritised integrative attending skills improve spontaneously in response to a broad range of ensemble experiences, they do not in themselves address any potential differences in the efficacy of specific practice versus general ensemble experience.

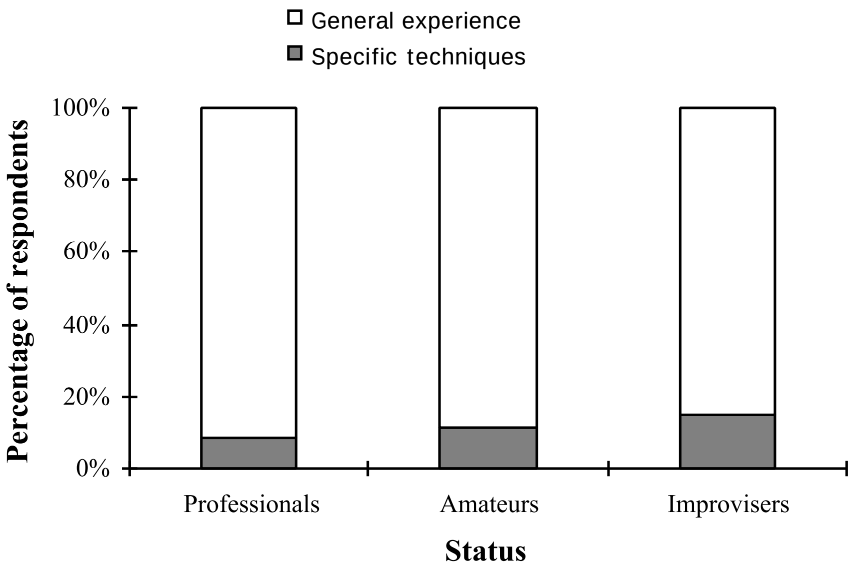


**Figure 2.6:** Percentage of musicians who indicated that prioritised integrative ensemble skills improve with specific rehearsal techniques and ensemble experience generally.

## 2.4.4 Discussion

### 2.4.4.1 Summary of EPQ results

Musicians’ responses to the EPQ indicate that prioritised integrative attending is considered to be optimal behaviour in the context of ensemble performance, especially by highly experienced orchestral performers (professionals) and those who engage in improvisation.

Furthermore, responses to open ended questions suggest that prioritised integrative attending is beneficial to the extent that it facilitates goals that generally relate to coherence of ensemble sound. More specifically, paying attention to one's own part and other parts enables the realisation of fundamental goals such as cohesion and coherence in terms of balance, intonation, and tempo, as well as more expressive goals such as rhythmic cohesion, pitch stability, and coherence in terms of artful timing deviations, phrasing, articulation, style, and tone colour. Although musicians of different status emphasised these goals to differing degrees (e.g., amateurs mentioned less sophisticated goals than professionals), rhythmic coherence emerged as being particularly important.

The EPQ also yielded information about the degree to which various musical and extramusical factors influence ability to engage in prioritised integrative attending. Responses provide evidence that ensemble musicians believe that prioritised integrative attending is affected to a greater extent by extramusical factors, than by musical factors. Of the extramusical factors included in the EPQ, musicians believe level of arousal and mastery of technique to be more influential than anxiety. Musicians' comments imply that these factors, in addition to factors relating to acoustic conditions, comfort, familiarity of the music, expertise of ensemble members, and social relationships, hinder prioritised integrative attending to the extent that they are distracting or attentionally demanding.

Amongst the musical factors considered, rhythmic complexity is believed to be most influential, followed by textural factors, tonality or harmonic context, melodic contour, and pitch interval size. In accordance with findings indicating that the general complexity of one's part is thought to affect prioritised integrative attending to a greater extent than the complexity of other parts, rhythmic complexity was deemed most influential when its locus was either the performer's own part, or the relationship between their own and other parts. According to musicians' comments, prioritised integrative attending is discouraged by increasing complexity in terms of the musical factors considered, in addition to other musical factors (including loudness, balance, frequency of meter change, instrumentation, style, tempo, and articulation).

Finally, responses to the EPQ indicate that performers typically feel the need to concentrate upon the task of simultaneously paying attention to one's own part and other parts. This suggests that prioritised integrative attending does not proceed automatically. Claims by amateur orchestral musicians to the effect that they are sometimes able to engage in prioritised integrative attending automatically, may reflect a tendency to merely presume that they are able to pay attention to other parts, when in fact they are preoccupied with their own part. Amateurs may make this assumption more readily than professionals and improvisers because they do not attribute as much importance to prioritised integrative attending. Alternatively, claims about automaticity may be taken to imply that the elementary goals recognised by amateurs (i.e., coherence in terms of balance, intonation, and tempo) may come to be realised by preattentive processes. On the other hand, the more expressive goals sought by professionals (e.g., rhythmic cohesion and consistent timing deviations) may require more focused attention. Nevertheless, the majority of musicians from all status groups acknowledge that prioritised integrative attending skills improve as a consequence of both specific practice and ensemble playing generally. More objective measures are required to determine whether specific practice is more effective than general ensemble experience.

#### 2.4.4.2 Implications of the EPQ results

Collectively, the findings of the EPQ have implications for both the formulation of a cognitive model of ensemble performance, and the development of a system of rehearsal techniques aimed at improving ability to engage in prioritised integrative attending. For instance, information about the relative influence of various factors upon prioritised integrative attending may play a role in the identification of the components that should be included in a valid model of ensemble performance, as well as providing loose guidelines about how these components might be weighted. At this stage, however, the description of a definitive model would be premature, as respondents listed several additional factors for which relative influence information is not yet available. Nevertheless, the information provided by the EPQ can be used as a basis for making some preliminary recommendations for (a) research into ensemble performance, and (b) the development of a system of progressive techniques designed to foster prioritised integrative attending. Findings about the relative importance of the various musical factors suggest that the manipulation of rhythm and texture in rehearsal techniques and experimental paradigms alike, may be initially more profitable than focusing upon pitch-related factors such as tonality or harmonic context, melodic contour, and pitch interval size.

The emergence of rhythmic cohesion as a primary goal in ensemble performance, and of rhythmic complexity as a factor that is highly influential in prioritised integrative attending, implies that in order to understand the processes involved in ensemble performance it is necessary to explicate the dynamics of the relationship between musical rhythm and attention. This is consistent with conventional wisdom in music of other cultures such as Africa and Indonesia, as discussed earlier in section 2.2.1. Furthermore, it suggests that Jones' dynamic attending approach (e.g., Jones, 1976; Jones & Boltz, 1989) may be an appropriate framework within which to consider prioritised integrative attending in ensemble performance. Application of this framework would suggest that prioritised integrative attending is facilitated by the process of attunement, whereby a listener/performer's attentional rhythms become synchronised with periodicities defined by the music's rhythmic structure. As mentioned earlier, Jones and Boltz (1989) propose that such attunements underlie the generation of the metric frameworks that are used to interpret rhythms. It follows that metric frameworks may function to facilitate prioritised integrative attending in ensemble contexts by promoting the efficient allocation of a performer's attentional resources. According to this proposal, such efficiency supports an attentional strategy flexible enough to enable separate parts to be 'scanned' with a view to integration. Clearly, the progress of prioritised integrative attending would be affected, not only by the rhythmic complexity, or metricality, of one's own part, but also by the degree to which the overall multipart structure (defined by the relationship between parts) can be accommodated by the same hypothetical metric framework. Some practical implications of this interpretation of the EPQ findings are discussed briefly in Appendix 2.10.

#### 2.4.4.3 EPQ Conclusions

The technique of surveying ensemble musicians has provided valuable insights into (a) the goals of ensemble performance, (b) the role of prioritised integrative attending upon the realisation of these goals, and (c) the effects of various musical and extramusical factors upon ability to engage in prioritised integrative attending. Musicians agree that prioritised integrative attending constitutes optimal, or adaptive behaviour in ensemble contexts, inasmuch as it facilitates the production of a cohesive and coherent ensemble sound, particularly in terms of rhythmic cohesion. Furthermore, the identification of rhythmic complexity as an especially significant influence upon prioritised integrative attending highlights the dynamic nature of the relationship between attentional processes and temporal structures defined by music. This relationship has implications for the formulation of a progressive system of techniques aimed at fostering prioritised integrative attending (see Appendix 2.10). However, rigorous behavioural experiments are necessary to develop objective indices of prioritised integrative attending that can be employed, first, to confirm the findings of the EPQ, and, second, to evaluate the efficacy of the rehearsal techniques. In addition, experimentation would be valuable as a means of extending the EPQ findings by examining the relationship between prioritised integrative attending and the interactions of factors that are possibly interdependent (e.g., rhythm and texture). Nevertheless, some clear and tangible hypotheses have emerged through interpretation of the EPQ findings. Perhaps the most cogent of these is the proposition that the generation of metric frameworks by a performer facilitates prioritised integrative attending in ensemble contexts. This invites a closer examination of precisely how the mechanisms that underlie metric frameworks mediate interactions with multipart rhythmic patterns.

## 2.5 Summary

Ethnomusicological accounts of rhythmic behaviour and the opinions of practicing Western ensemble musicians provide converging evidence that prioritised integrative attending constitutes optimal behaviour in multipart rhythmic contexts. The ensemble musicians surveyed reported that prioritised integrative attending was especially important in the realisation of ensemble performance goals related to rhythmic cohesion. Furthermore, they indicated that rhythmic complexity is the musical factor that most profoundly influences ability to engage in prioritised integrative attending. Although this is consistent with the proposal that metric frameworks play a role in facilitating the attentional flexibility that is requisite for prioritised integrative attending, it does not make explicit the exact nature of the mechanisms involved.

# CHAPTER 3

# METER, FLEXIBILITY, AND RESOURCE ALLOCATION IN PRIORITISED INTEGRATIVE ATTENDING

In this chapter, hypotheses are developed about how metric frameworks enable prioritised integrative attending. First, the attentional mechanisms that underlie metric frameworks are described in terms of expectancies and schemas. Then the idea that these mechanisms are sufficiently flexible to allow attention to be directed to both integrant and aggregate aspects of multipart patterns is explored. Concurrent processing of integrant and aggregate patterns is considered as a multipart complex task requiring attentional resource allocation. It is ultimately proposed that metric frameworks function as attentional schemes that guide the process of attending to separate parts in multipart rhythmic textures.

## 3.1 Introduction

In preceding chapters, the proposition that metric frameworks play a role in mediating multipart musical rhythmic interactions was developed. This proposal is founded upon the assumption that metric frameworks promote both efficient processing and representation of temporal event sequences. Extending this assumption leads to the claim that these types of efficiency enable the attentional flexibility that is requisite for prioritised integrative attending, which, according to a survey of practising ensemble musicians (see 2.4), constitutes optimal behaviour in ensemble contexts. Metric frameworks thus facilitate multipart musical interactions such as ensemble performance. However, the exact nature of the attentional mechanisms involved in the generation of metric frameworks has not been examined. Furthermore, the manner by which these mechanisms may promote attentional flexibility needs to be addressed.

## 3.2 Attentional mechanisms underlying metric frameworks

### 3.2.1 Metric frameworks as expectancies and schemas

Metric frameworks are often described in terms of psychological concepts such as *expectancy* and *schema* (Clarke, 1987b; Desain, 1992; Jones, 1981, 1982, 1990; Narmour, 1992; Palmer & Krumhansl, 1990). In a general sense, expectancy is the experience of perceptually anticipating an event. Such anticipation serves to enhance the processing of the event by preparing, or 'priming', the perceiver for its occurrence (Bharucha, 1987; Jones, 1976; Posner & Snyder, 1975; Schmuckler, 1989). Expectancies are typically considered to be driven by fairly low-level perceptual mechanisms that are innate, proceed subconsciously, and operate in a bottom-up fashion (i.e., they detect structural organisation rather than impose it). On the other hand, schemas are commonly viewed as domain specific knowledge structures that guide the interpretation of perceptual input (Bartlett, 1932; Neisser, 1967). As such, they are characterised as higher-level cognitive mechanisms that are learned, can be consciously invoked, and are top-down (i.e., they may impose a subjective organisation even when none is objectively present).

Schemas function similarly to expectancies, in the sense that they facilitate the efficient processing of an event by priming appropriate perceptual and cognitive mechanisms. Hence, it is sometimes held that schemas are sets of expectancies that have been associated by past experience (Bharucha, 1987; Jones, 1981, 1982, 1990). However, schemas differ fundamentally from expectancies in that they guide the interpretation of perceptual input in accordance with pre-existing categories that are thought to be learned through processes such as cultural conditioning (Francès, 1988). These categories provide context dependent default input values, which – although presumably intended to serve adaptively to permit efficient resolution of ambiguous or degraded input – have been found to distort, or bias, perception under a wide variety of circumstances (e.g., Bartlett, 1932; Bharucha, 1987; Biederman, 1981; DeWitt & Samuel, 1990; Neisser, 1967).

The concepts of expectancy and schema have been used to explain many aspects of musical behaviour. Schmuckler (1989, p. 111) asserts that “Almost all contemporary music-theoretic analyses have adopted implicit or explicit ideas of expectation”. Notably, expectancy and schema have been implicated as mechanisms involved in (a) the appreciation of aesthetic value and emotional meaning in music (Meyer, 1956), (b) the comprehension of melodic structure (Dowling, 1978; Narmour, 1989, 1990, 1992), (c) the mental representation of tonal relations (Krumhansl, 1990; Krumhansl & Kessler, 1982), (d) the recognition of harmonic relationships (Bharucha, 1987; Bharucha & Stoeckig, 1986, 1987; Krumhansl & Castellano, 1983), (e) the representation of large-scale formal structure (Lerdahl, 1991), (f) the interpretation of rhythm patterns (Bamberger, 1980; Boltz, 1989; Bharucha & Pryor, 1986; Desain, 1992; Martin, 1972; Palmer & Krumhansl, 1990), and (g) various combinations of the above elements of musical behaviour (Boltz, 1993; Bregman, 1990; Clarke, 1986; DeWitt & Samuel, 1990; Francès, 1988; Jones, 1981, 1982, 1990; Krumhansl, 1992; Leman, 1995; Lerdahl & Jackendoff, 1983; Schmuckler, 1989, 1990; Schmuckler & Boltz, 1994; Umemoto, 1990).

Models of rhythmic behaviour generally provide accounts of metric pulse formation that are based upon expectancies and schemas. Parncutt (1994a, p. 453) implies that this is unavoidable: “A sensation of pulse may be regarded as a trivial form of expectancy. Once a pulse sensation is established, events are ‘expected’ at equal time intervals. A definition of rhythm based on pulse sensation thus automatically incorporates the notion of expectancy.” Accordingly, representational models, algorithmic-procedural models, and dynamic-procedural models all postulate mechanisms that can be conceived in terms of the expectancy concept. However, the latter two classes of model are more explicit in their descriptions of the relationship between expectancy and meter. The metric hypothesis testing process in the algorithmic-procedural model of Longuet-Higgins and Lee (1982) incorporates a series of steps in which temporal expectancies are first established, and then either confirmed or refined. The concept of expectancy features even more prominently in dynamic-procedural approaches (e.g., Desain, 1992; Jones & Boltz, 1989; Large & Jones, 1999). This may be a result of their emphasis upon the interactive nature of the linkage between an individual's cognitive apparatus and external temporal structures.

### 3.2.2 Generating expectancies and expectancy schemes

In Jones' (1976, pp. 340-341) dynamic attending theory, "listeners are assumed to generate initial expectancies… along simplified schemas… In a real sense, perception begins with the listener's expectancies". Since then, Jones (1981, 1982, 1990) has provided detailed descriptions of how expectancies and schema-like 'expectancy schemes' come to form the basis for perceptual reference frames such as metric frameworks.

In Jones' approach, expectancy formation is contingent upon an individual abstracting information about invariant (i.e., recurrent) temporal or pitch relationships from a pattern. This information is extracted through a process whereby the individual directs attention over time spans that are compatible with their biologically-based rhythms (oscillators). Pattern invariants that are consistent with these attending rhythms (such as those whose pitch-time trajectories are confined to the serial integration region – see 1.2.3.2.2) are rendered "immediately compelling" (Jones, 1990, p. 195). The abstracted invariants are then used to generate expectancies about when (in time) and where (in pitch space) the next event that corresponds to the attended time span will occur. More specifically, the invariants are translated into expectancies via the application of generator rules (embodied in oscillator activity) that involve simple ratio transformations. Each expectancy is a "space-time vector" that ranges over a "*single* time span" (Jones, 1990, p. 200). Attunement ensues if a series of expectancies is confirmed by events occurring in the anticipated pitch-time locales: "Synchronisation… merely reflects a verification process" (Jones, 1976, p. 341).

In temporally coherent events, expectancies may be simultaneously generated over several different time spans. These expectancies may then become linked into expectancy schemes. In expectancy schemes, individual expectancies are temporally nested to form time hierarchies that mirror those implied by the structure of the attended pattern. Thus, "Expectancy schemes interrelate expectancy vectors into coordinated sets" (Jones, 1990, p. 212-213). This interrelationship may lead to the formation of metric frameworks, with one series of expectancy vectors defining beat-level pulsations, and another defining bar-level pulsations. The characterisation of metric frameworks as dynamic expectancy schemes implies that perhaps they are not schematic knowledge structures in the traditional sense. In fact, Jones (1990, p. 217) maintains that there is no “storage of either a time hierarchy or time levels” associated with metric frameworks. Instead of pre-existing as templates, they may emerge as relatively plastic real-time responses to unfolding musical patterns.

Desain (1992) has formulated an expectancy-based theory of rhythm perception that he considers to be a connectionist formalisation of concepts described by Jones. Desain proposes that expectancies develop as a function of experiencing a temporal interval (between two events) and the time elapsed after the interval. A basic expectancy curve extends from this interval, with peaks occurring when the time elapsed is an integer divisor or integer multiple of the interval. A global expectancy curve then results from the summation of the basic expectancies generated by all the intervals in the pattern. In the global expectancy curve, local maxima represent the location of expected events, and local minima represent unexpected event locations. The peaks of the maxima are located at time points which represent a ‘good continuation’ (in terms of temporal ratio preservation) of the pattern. As in Jones’ formulation, each new event presented by the unfolding pattern can either reinforce the extant global expectancy curve or violate it.

The distinction made by Desain between *basic expectancies* and *global expectancy* is analogous to Jones’ distinction between *individual expectancies* and *expectancy schemes*. However, Jones and Desain make different claims about the type of information that prompts the formation of low-level individual expectancies. Whereas Jones suggests that only invariant temporal intervals, such as those defined by periodically occurring elements, contribute to expectancy formation, Desain claims that basic expectancies are generated in response to each and every temporal interval contained in a pattern. Nevertheless, their approaches consider the relationship between expectancy schemes and metric frameworks from a common viewpoint. Like Jones, Desain (1992, p. 450) rejects the notion of meter as a static schematic template: “instead of deriving a symbolic notion of meter from these curves, it might be more productive to rethink the concept of meter as a continuous concept, an idealised expectancy curve”.

### 3.2.3 Bottom-up and top-down aspects of metric frameworks

Models of rhythmic behaviour are sometimes classified according to whether they describe bottom-up or top-down processes (e.g., Todd, 1994). In general, representational models are top-down – they attempt find the best match between whole patterns and pre-existing hypothetical metric frameworks. On the other hand, algorithmic-procedural models emphasise bottom-up processes, such as extracting hypothetical metric units from inter-onset intervals and/or durations marked in the early stages of an unfolding pattern, although some do have top-down aspects that usually manifest themselves as *preferences* for particular metrical interpretations. Indeed, it is often difficult to make neat top-down/bottom-up classifications because recent models seem to recognise the utility of considering both processing routes. For example, Todd (1994, p. 27) states that "(t)he rhythmic interpretation of a sequence… is the consequence of both top-down processes and bottom-up processes". Narmour (1992, p. 12) explicates the relationship between these routes nicely:

> "Bottom-up perceptual processing is… a mechanical operation, brutely analyzing all the input data that come its way, whereas top-down cognitive processing spreads hierarchically downward, from highly generalised knowledge structures to gradually more detailed isomorphic mapping. Both tracks are independent and thus always simultaneously operate in the comprehension and assimilation of incoming stimuli".

Narmour proposes that the distinction between metric pulse and metric hierarchy reflects the difference between bottom-up and top-down processes, respectively. Thus, he assumes that the experience of metric pulsations is related to basic expectancy generation, whereas the hierarchical relationship that obtains between pulsation levels in metric frameworks has schema-like properties.

Narmour's differentiation of metric pulse and metric hierarchy is similar to Jones' distinction between a series of individual expectancies and an expectancy scheme. However, unlike Narmour, Jones does not categorically associate expectancies with bottom-up processes and expectancy schemes with top-down processes. For instance, Jones (1990, p. 207) implies that basic expectancy generation is mediated by both bottom-up and top-down processes: "Constraints on acceptable (i.e., entrainable) values of time periods for a 'felt beat' derive partly from biological determinants and partly from cultural norms".

And then, although Jones' claim that cultural learning reinforces expectancy schemes suggests that they incorporate schema-like properties, they are not schemas in the traditional sense because they are not envisaged as stored knowledge structures. Desain's (1992) characterisation of global expectancies is compatible with this. The notion that expectancy schemes are not structurally equivalent to traditional schemas challenges the conception of metric frameworks as mere schematic templates (i.e., the assumption underlying most representational models).

Even though expectancy schemes (or global expectancies) and traditional schemas appear not to be structurally equivalent, they do share functional attributes. For instance, like traditional schemas, expectancy schemes can influence perception in a top-down fashion. As expectancy schemes, metric frameworks are thought to be quite potent in this regard. Metric frameworks are fairly resistant to disruption once they are generated. It is commonly acknowledged that the 'metrical inertia' (Clarke, 1986) or 'momentum' (Yeston, 1976) established by metric frameworks can influence, or bias, the interpretation of later events. Clarke (1986) likens this to the 'Garden Path' concept, invoked in discussions of linguistic ambiguity (e.g., Clark & Clark, 1977), whereby the structure of early sections of a sentence may influence drastically the comprehension of later sections.

In psychological investigations of musical rhythmic behaviour, the robustness of metric frameworks sometimes causes metrical 'carryover' effects (Jones, 1985; Povel & Essens, 1985; Yee et al., 1994). These effects occur when a metric framework induced in response to patterns presented early in an experimental procedure is used by the listener to interpret subsequent patterns, even if it is not the best fitting framework. The top-down, schema-like qualities of expectancy schemes generally, and metric frameworks in particular, are also evidenced by the fact that they can be generated spontaneously by an individual in the absence of an external pattern.

### 3.2.4 Reactive versus proactive metric framework generation

The process of abstracting invariants from an external pattern, and using these as a basis for generating metric frameworks is essentially *reactive*: the pattern is presented, and then the individual responds by extracting the useful structural information from it. *Reactive metric framework generation* assists the *encoding* of presented patterns. That is, it facilitates the stage of processing in which internal representations are formed for external patterns. On the other hand, the *retrieval* of stored pattern representations from memory is accompanied by a more *proactive* style of metric framework generation. *Proactive metric framework generation* occurs when an individual more or less spontaneously invokes a metric framework which is used to guide recall.[7] Thus, the generation of metric frameworks can play a similar role during encoding and retrieval.

This is consistent with Jones' dynamic attending approach, in which it is assumed that the same expectancy schemes guide attending during encoding and retrieval. Jones (1981, p. 575) claims that the "generator for remembering some relationship between events is merely the inverse of the time generator that moves the expectancy scheme for anticipating these same events. Remembering then involves directing attention into negative time… Expectancy and remembering then are opposite sides of the same coin". In other words, recall "recapitulates the attentional activities that guided perception" (Jones, 1985, p. 207). Similarly, expectancy-based approaches to various aspects of music cognition describe how expectancies and schemas affect the interpretation of past, as well as current, events (e.g., Bharucha, 1987; Schmuckler, 1989). These views are consistent with a more general 'proceduralist' position that sees memory as the persistence of mental activity associated with processing an event, rather than as a faculty for depositing information in a store (e.g., Crowder, 1993a, 1993b; Kolers, 1973; Kolers & Roediger, 1984). Thus, memory for temporal events can be modelled as the ongoing resonance of processing activity through a neuronal system (Large & Kolen, 1994).

Establishing strong links between the processes that occur during encoding and retrieval implies that reactive and proactive metric framework generation recruit the same underlying mechanisms. Nevertheless, it is useful to distinguish between these two styles of metric framework formation for several reasons. First, making this distinction highlights the dual routes to metric framework formation: reactive generation involves both bottom-up and top-down processes, whereas proactive generation clearly involves only schema-like top-down processes. Second, distinguishing between reactive and proactive generative styles allows more detailed descriptions of musical behaviours that vary in terms of whether they present greater demands at encoding or retrieval. For example, listening to an unfamiliar piece presents demands that relate primarily to encoding, whereas the demands associated with performing a piece from memory are related to retrieval. Considering the

[7] These terms refer mainly to the initial stages of metric framework generation, as frameworks that are initiated reactively may acquire top-down properties if maintained throughout a particular musical interaction.

unique characteristics of the various circumstances under which metric frameworks are generated may contribute to a fuller appreciation of their ecological functions.

### 3.2.5 Ecological functions of expectancy schemes and metric frameworks

The expectancy schemes that underlie metric frameworks have similar functional properties to the mental sets and cognitive frameworks described earlier: they organise information into meaningful categories, and thereby provide a basis for comprehending events in terms of both their structure and ecological significance. In fact, Jones (1982, p. 2) claims that an expectancy scheme is a "rhythmically based mental set". Such schemes therefore serve as "perceptual reference frames which are attentional anchor points" (Jones, 1990, p. 214). Jones (1982, 1990) describes how attention can be cast out from these anchor points towards regions in time and pitch space in accordance with a listener's goals. Expectancy schemes thus assist in preparing a listener for future events by allowing attention to be guided over many different time levels defined in the current environment (Jones, 1982, 1990). Shifting attention between these levels facilitates the comprehension of an event by allowing the listener to consider it from different temporal perspectives (Jones, 1992; Jones & Boltz, 1989). However, it is access to higher-level time spans that appears to be a particularly beneficial concomitant of expectancy scheme activation. Accordingly, expectancy formation is associated with attunement and future-oriented attending, but not analytic attending, in the dynamic attending approach (Jones & Boltz, 1989).

It was argued in Chapter 1 that metric frameworks function adaptively by facilitating both the processing and representation of temporal structures in the environment. Considering the schema-like aspects of metric frameworks provides some insight into how they may come to promote efficient representation and processing. The properties that render metric frameworks suitable for use as perceptual reference frames (i.e., their hierarchical structure and robustness) facilitate representational efficiency by providing a basis for the categorisation of rhythmic elements. This efficiency is a consequence of not only the quantisation process underlying categorical rhythm perception (see 1.2.3.3), but also of the establishment of equivalence classes that reflect the recursive nature of meter (e.g., the *n*th beat of the bar – see Benjamin, 1984; Lewin, 1984; Parncutt, 1994a). Furthermore, the properties of metric frameworks that enable them to define attentional trajectories (i.e., their relation to dynamic expectancies and attunement) facilitate processing efficiency by priming, or preparing, appropriate processing mechanisms. Such preparedness allows attention to be targeted purposefully and flexibly. The benefits of this attentional flexibility are most fully realised in the context of interactions with multipart rhythmic textures. Indeed, Boltz (1993, p. 597) proposes that "expectancy generation enables a listener to initiate preparatory responses that may be required in a cognition experiment or in the context of a more ecological setting, the synchronization and smooth exchange of instruments during a concert performance".

## 3.3 Metric framework generation and attentional flexibility in singlepart and multipart contexts

### 3.3.1 Choosing the pulse

In multipart rhythmic textures, there are usually several potential sources from which the invariants that provide a basis for metric framework generation can be abstracted. For instance, information about underlying periodicities may be extracted either from individual integrant patterns, or from the aggregate pattern that results from their combination. And, to complicate matters further, a given integrant pattern may best fit a different meter to other complementary integrant patterns and/or the aggregate pattern (e.g., in hemiola). The question of which of these sources to select as a basis for generating the beat- and bar-level pulses of metric frameworks is presumably resolved in accordance with both biological constraints and the individual's listening or performance goals. Some issues relating to these selection bases have been investigated in the context of polyrhythmic patterns (e.g., Handel & Lawson, 1983; Jones et al., 1995), and other simple multipart contexts (Klein & Jones, 1996). However, as pointed out in section 1.2.3.2.2, it is unclear whether the findings of these investigations are generalisable to the types of structures and demands associated with complex multipart contexts such as those encountered in musical ensemble performance. Hence, it is necessary to consider situations where integrant patterns are highly differentiated (and possibly nonmetrical), and where a prioritised integrative attentional strategy, in which integrant and aggregate textural levels are simultaneously attended, is employed.

Issues concerning the number of metric frameworks that can be simultaneously activated by an attender are raised by the possibility that integrant and aggregate aspects of multipart patterns may best fit different, even conflicting, meters. When this question is restated in the language of the dynamic attending approach, it becomes an issue of the number of attentional oscillators invoked, as well as the strength of the connections between these oscillators. Klein and Jones (1996) imply that a separate attentional oscillator is engaged for each entrainable periodicity inherent in a pattern's structure. The connection strength between oscillators varies as a function of the ratio complexity of the relationship they define. Strong connections are obtained when the ratio between oscillator periods is simple (e.g., 1:1, 2:1, 3:1), whereas weak connections arise from complex oscillator period ratios (e.g., 4:3, 5:4, 6:5). Dynamic attending concepts are applied to some basic multipart structures in the remainder of this section.

It is possible that in a multipart context such as the pattern notated in Figure 3.1, a different attentional oscillator[8] may become associated with each integrant pattern. So in response to the concurrent presentation of the isochronous integrant patterns in Figure 3.1 (see Track 20), three oscillators might be invoked: each one becoming synchronised with either the 600 ms, 1800 ms, or 2400 ms periodicity. This relies on the assumption that all three satisfy biological constraints relating to the timescale at which attunement, and hence metric pulsation, is experienced. The 2400 ms period is perhaps questionable in this regard, given that it lies outside of what Parncutt (1994a) calls the existence region of pulse sensation (see 1.2.1.2). Nevertheless, Jones and Boltz (1989) argue reasonably that the limits on attunement are context dependent and relative, rather than absolute. Furthermore, although the structure of each integrant pattern (and indeed the resultant isochronous aggregate pattern) can be specified according to a 600 ms periodicity alone, such a solution does not take full advantage of the higher-level periods that support future-oriented attending.

Once the three oscillators are engaged, several different patterns of connectivity may ensue. Coupling oscillators with 600 ms and 1800 ms periods produces strong connections in the simple ratio of 3:1. This defines a triple meter where the 600 ms period corresponds to a beat-level pulse and the 1800 ms period corresponds to a bar-level pulse. Similarly, coupling the 600 ms oscillatory period with the 2400 ms oscillatory period results strong connections in a simple 4:1 ratio defining a quadruple meter. However, complex ratios,

[8] The term 'attentional oscillator' is used here both for convenience and out of loyalty to the dynamic attending approach. However, as the precise identity of these oscillators is unknown, the term could be replaced by other terms that imply continuous periodic modulations in the amplitude of neural activity (e.g., 'attentional pulse' or even 'pulsator').

and consequently weak connections, are produced if the 1800 ms and 2400 ms oscillators are coupled (4:3), or if all three oscillators are connected (12:4:3). These complex ratios indicate a polymetric structure in which triple and quadruple meters are combined.

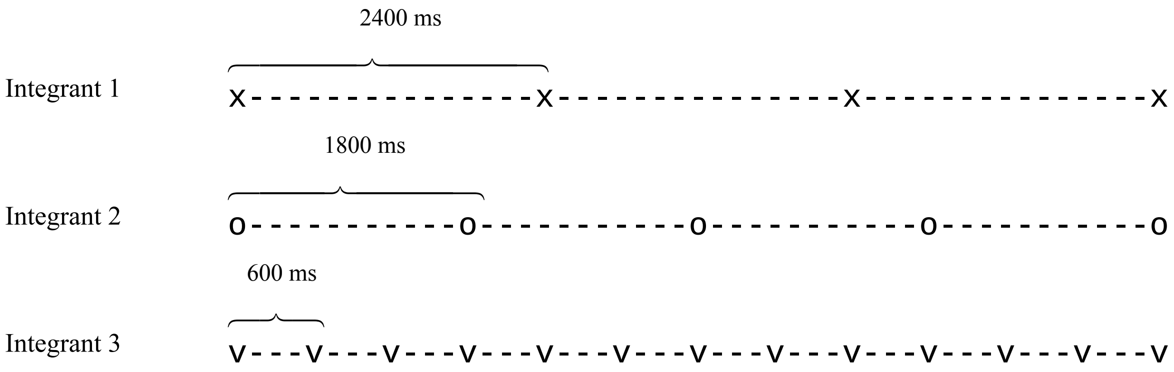


**Figure 3.1:** Isochronous integrant patterns whose periodicities are mirrored in oscillator activity.

It may be the case that the process of selecting which of these patterns of connectivity to use as the guiding metric framework is influenced by the strength of the connections they embody. This follows from Jones and Boltz's (1989, p. 472) assumption that "Attenders have biases for simple time symmetries". Hence, the strong connections associated with the triple framework and the quadruple framework ensure that they are compelling candidates, whereas the weak connections associated with the polymetric frameworks militate against their selection. Indeed, it is unclear whether the simultaneous use of multiple metric frameworks is a common attentional strategy in individuals with average levels of musical experience.

Nevertheless, such strategies may be available to individuals who have considerable experience with music characterised by polymetric structures. Bregman's (1990) views can be taken to support this proposal if the correspondence between schemas and metric frameworks is accepted. He argues that if a sound event contains more than one pattern, and if each of these patterns is associated with a different schema, a combination of simultaneously activated schemas may arise: "Sometimes the pattern of activated schemas will form a larger pattern that the perceiver has experienced in the past. In this case the pattern of activity of schemes can evoke a higher-order schema" (Bregman, 1990, p. 402). This implies that individuals with high levels of musical experience may be able to maintain and use more than one metric framework simultaneously, although such a split is yet to be demonstrated experimentally. Indeed, the psychological reality of polymeter is perhaps uncertain, as it could be argued that polymetric musical structures can be interpreted according to a single complex metric scheme.

If a polymetric framework does not emerge as a promising candidate for use in the interpretation of the multipart pattern in Figure 3.1, attenders might find themselves in a position where they must choose between a triple framework and a quadruple framework. The existence of more than one plausible framework indicates that the pattern's structure is metrically ambiguous. Jones and Boltz (1989) suggest that structural ambiguity generally can be resolved by employing a strategy that involves shifting attention between different levels of attunement. These levels typically include the referent level (i.e., the most salient pulse currently experienced) and several neighbouring levels that are higher and lower than the referent. The shifting strategy allows the attender to examine events at these different hierarchical levels, which each constitute a different temporal perspective from which to consider the pattern. Thus, attending style may switch between future-oriented and analytic attending in accordance with the individual's listening goals. When the goal is to disambiguate metrical structure, the strategy adopted presumably involves shifting attention between the pulsation levels that are unique to each candidate framework, and eventually settling upon whichever framework yields the most coherent interpretation of the pattern. In order to employ such a shifting strategy, the attender must be able to transfer their attentional energy between levels with a high degree of flexibility (Jones & Boltz, 1989). This requisite flexibility is constrained by several factors, including pattern complexity, the attender's skill, and demands associated with the goals of the interaction between the attender and the pattern.

### 3.3.2 Rhythmic complexity

Jones and Boltz (1989) propose that attentional flexibility varies as a function of temporal coherence, which is synonymous with rhythmic complexity (metricality). Specifically, attending becomes less flexible in events with low coherence, where generative time rules contain complex and/or inconsistent ratios. This sort of complexity ensures that local temporal expectancies are frequently violated. These violations disrupt the process of attunement and thereby make processing discontinuous and relatively inefficient. Consequently, the hierarchical levels that support attunement are limited in less coherent events, and hence attunement shifts are rare. However, in relatively coherent events, expectancies typically experience only a milder degree of violation, and therefore processing is efficient and attending is flexible. A complexity-flexibility trade-off therefore emerges, wherein increases in pattern complexity are accompanied by decreases in attentional flexibility (see Figure 3.2). The shape of the hypothetical complexity-flexibility trade-off function in Figure 3.2 resembles an inverted 'S', and is based loosely on the ideas of Jones and Boltz (1989). An initially gradual decline in flexibility reflects tolerance to low levels of expectancy violation. This tolerance is engendered by the top-down aspects of metric framework generation. The initial gradual decline is followed by a sharp drop in flexibility at a point in the complexity continuum marking the threshold at which metrical interpretations are no longer feasible.

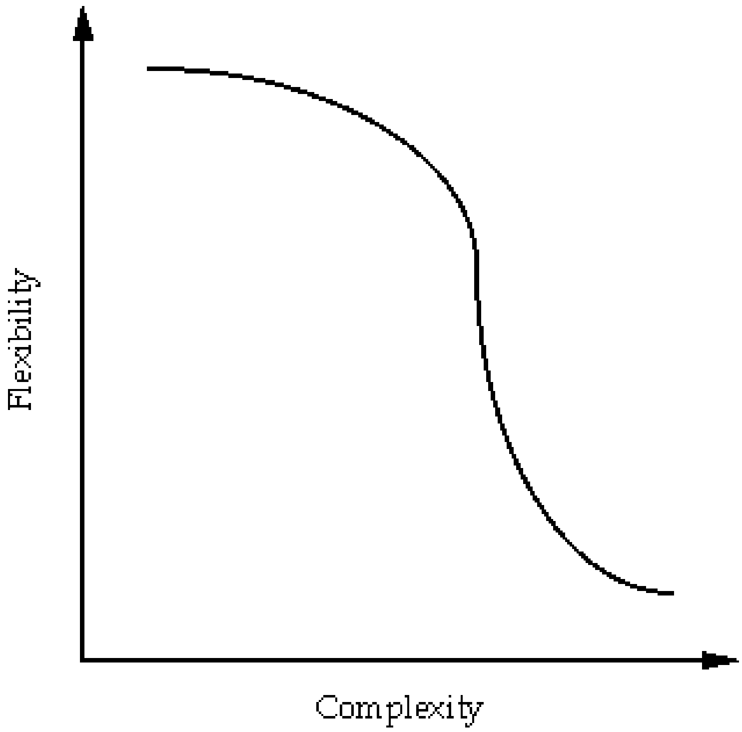


**Figure 3.2:** Hypothetical complexity-flexibility trade-off function. Moving to the right on the horizontal axis indicates increasing complexity. Moving up on the vertical axis indicates increasing attentional flexibility.

In multipart contexts, rhythmic complexity may be considered as a property of either the individual integrant patterns, or the aggregate pattern. Moreover, there may be some independence between the temporal coherence displayed by integrant and aggregate patterns. For example, it is possible that although individual integrant patterns may be coherent in themselves, they may combine to form relatively incoherent aggregate patterns (e.g., polymeter). Conversely, situations arise where apparently incoherent integrant patterns combine to form coherent aggregate patterns (e.g., hocket).

The complexity of the relationship between integrant and aggregate aspects of multipart patterns has been found to affect the type of attentional strategy they support. Klein and Jones (1996) demonstrate that, when an integrant pattern is coherent in itself, but forms an incoherent relationship with another concurrent integrant pattern, attention to the individual integrant patterns is more readily achieved than attention to the aggregate pattern. On the other hand, when a coherent relationship obtains between both integrant patterns, attending to the aggregate pattern is facilitated more than attending to integrant patterns individually. These findings imply that flexibility of attentional strategy is constrained by the coherence of the relationship between different integrant patterns, as well as the coherence of the relationship between integrant patterns and the aggregate pattern in which they are embedded. So, although temporal coherence generally facilitates shifts in attending, shifting between attunement levels that correspond to different integrant patterns, or to a particular integrant pattern and the aggregate pattern, may be discouraged when these various multipart pattern aspects best fit different meters.

Coherent hierarchical structuring is not sufficient for promoting a flexible attentional strategy. There are limits to the amount of information that can be attended to and processed even in musical events that are structured according to strict hierarchies (Swain, 1986). In the dynamic attending approach, the limits to feasible number of levels in hierarchies such as metric frameworks are expressed as dominance region constraints (Jones & Boltz, 1989). Dominance region constraints ensure that "attenders can only shift attending so far before the connection between an established referent and a remote focal level breaks" (Jones & Boltz, 1989, p. 473). It may be the case, however, that the number of potential levels, and the flexibility with which attention can be shifted between these levels, increase with the attender's skill.

## 3.3.3 Attending skills: Effects of musical training

### 3.3.3.1 Learning to use metric frameworks

Jones (1990, p. 225) proposes that "With greater experience, more refined and complicated expectancy schemes develop and these insure that the educated listener can flexibly shift attending over different time levels to achieve a greater understanding of the music event". Thus, musically skilled attenders (musicians) may have richer, more fortified metric frameworks at their disposal than unskilled attenders (nonmusicians). In support of this, it has been demonstrated that trained musicians are able to attend to higher and lower levels of hierarchical event structures than untrained individuals (Jones & Yee, 1997; Jones et al., 1995; Palmer & Krumhansl, 1990; Yee et al., 1994). In fact, skilled individuals typically extrapolate beyond (both above and below) levels marked explicitly by periodic pattern elements. The benefits of attending to higher levels seem reminiscent of those that accrue to experts in various domains (e.g., chess), who are able to deal with larger amounts of information than novices, through the use of chunking strategies (Miller, 1956). On the other hand, attending to levels lower than those explicitly marked by pattern elements allows finer temporal acuity, and is achieved by mentally subdividing the shortest marked periodicity (Yee et al., 1994; Jones et al., 1995).

The extra focal levels available to skilled musicians provide them with a broader range of temporal perspectives that can be exploited in attempts to resolve structural uncertainties such as metrical ambiguity. Experience in a particular musical culture may affect how such ambiguities are resolved by introducing preferences for certain meters over others. For example, there appears to be a somewhat tacit consensus that experience with Western music may engender a bias towards metric frameworks with a binary generative basis (duple and quadruple meters), over those with a ternary structure (triple meters) (e.g., Lerdahl & Jackendoff, 1983). Binary biases in rhythmic interpretation have been demonstrated in experiments with both adults (Bolton, 1894; Parncutt, 1994a; Smith & Cuddy, 1989) and children (Upitis, 1987) experienced in Western music.

Lerdahl and Jackendoff (1983, p. 101) provide a formal description of a binary bias in their *metrical preference rules* (MPRs): for example, MPR10 (Binary Regularity) states: “Prefer metrical structures in which at each level every other beat is strong”. Although Lerdahl and Jackendoff lean towards the position that metric preferences are innate predispositions, they at the same time claim that their theory of tonal music overall is a “formal description of the musical intuitions of a listener who is experienced in a musical idiom” (p. 1) and that “it is not hard to make a case for some aspects of musical grammar being idiom specific” (p. 279). It should be noted that some have argued that Lerdahl and Jackendoff’s distinction between innate and learned capabilities is founded on slippery ground (see Clarke, 1986).

Historically, the bias in Western listeners has not always been towards binary organisation. From the late twelfth century to the fifteenth century there was an apparent preference for ternary organisation in Western church and court music. Indeed, treatises of the time distinguished between ternary ‘perfection’ and binary ‘imperfection’ (Sachs, 1953). The origins of this preference are uncertain. Music historians have attributed it to a variety of religious, mathematical, and aesthetic considerations, some of which are mentioned briefly below.

#### *3.3.3.1.1 Digression into the Gothic age*

Franco of Cologne (in his circa 1260 treatise *Ars cantus mensurabilis* [The Art of Mensural Song]) claims that the perfection of ternary organisation derives from its numerical association with the Holy Trinity. More recently, scholars have questioned Franco's claim. Hoppin (1978, p. 335) argues that "It was probably not theological symbolism but rather the place of music as a mathematical discipline in the quadrivium of university studies that was largely responsible for equating perfection with the ternary units of the rhythmic modes". Specifically, three was held to be the most perfect number because it is the first to have a beginning, middle, and end. However, this proposal contrasts strongly with the explanation offered by Sachs (1953). He proposes that ternary perfection stems from the "specific character of ternary rhythm and from its fitness to answer the needs of the Gothic age" (Sachs, 1953, p. 160). These needs relate to a penchant for additive elements in Gothic art generally. Sachs uses the term 'additive' to refer to compositional techniques that result in artworks wherein unity is a property of individual elements, or separate creative stages, more so than of the complete work. This aesthetic apparently permeated painting, theatre, and architecture, as well as music: "Nowhere was integration intended; the ruling concept was x + y + z" (Sachs, 1953, p. 170). According to Sachs (1953, pp. 168-169), in musical rhythm "3/8, 3/4, and 3/2 live midway between divisive and additive rhythms. Their physiological character is 'breathing' rather than 'striding'…". Therefore, ternary structures were appealing in Gothic times because they allow musical time to be segmented with some degree of unevenness.

#### *3.3.3.1.2 Effects of culture and training upon metric preferences*

The fairly detailed discussion of binary versus ternary organisational preferences above illustrates some of the possible sociological factors that may influence the musical style adopted by a given culture. Experience with the culturally specific style may engender biases towards certain musical rhythmic interpretations over others. In support of this, rhythmic perceptual tendencies have been observed to differ systematically between individuals with different cultural backgrounds (Igaga & Versey, 1977, 1978). According to Jeff Pressing (personal communication, 19 June 1998), "there are documented effects about Westerners perceiving many West African patterns in 3/2 or 6/4 when the indigenous perception is closer to 12/8. Western listeners will tend to favour the meter which gives a simpler result – less syncopated".

The proposal that idiom specific metric preferences can be developed is consistent with the common assumption that a wide range of musical abilities and preferences are profoundly influenced by one's music cultural milieu (e.g., Campbell, 1991; Davies, 1978; Francès, 1988; Shepherd & Wicke, 1997; Sloboda, 1985b; Swain, 1994). Furthermore, just as learning schemas contributes to expert performance (Custers, Boshuizen, & Schmidt, 1998; Dufresne, Gerace, Hardiman, & Mestre, 1992), so the development of metric preferences may distinguish musicians from nonmusicians. Accordingly, Jones (1982, p. 2) posits that "(u)sually the paths of an expectancy scheme will follow simple genre specific musical rules. This means that skilled listeners will often be better at identifying clues to appropriate prototypes than unskilled listeners". Skilled listeners are advantaged because the expectancy schemes (e.g., metric frameworks) related to prototypical pattern structures are reinforced through cultural learning (Jones, 1990). Musical training presumably provides extra opportunies for such learning by encouraging a great deal of exposure to the musical environment.

It has been suggested that, as a consequence of exposure to a sample of culturally specific music, individuals are able to assimilate information about statistical regularities in the way certain musical features occur in the entire corpus of music that belongs to the relevant culture (e.g., the frequency with which events occur at different metric locations). Palmer and Krumhansl (1990, p. 730) propose that "Through experience, listeners may internalize musical relationships reflected by these statistical regularities and apply this knowledge to recognize music in that style… the temporal regularities in musical compositions may provide insights into the perceptual organization of meter". Thus, individuals may come to develop preferences for certain metric interpretations over others based on musical experience. Circumstances may arise where these learned preferences are forced to enter into competition with preferences that derive from biological constraints, such as those imposed on oscillator activity (Glass & Mackey, 1988; Klein & Jones, 1996). If the strength of metric preferences resulting from cultural learning is related to amount of exposure (as suggested by frequency-of-occurrence-based accounts, e.g., Palmer & Krumhansl, 1990), learned preferences should be more likely to prevail over biologically-based preferences in musicians than in nonmusicians. At present, however, evidence in support of this appears to be mainly anecdotal. Cross-cultural studies are clearly needed to determine the extent to which cultural learning can overcome biological constraints on metric preferences.

#### *3.3.3.1.3 Effects of training and complexity upon attentional flexibility*

So it appears that attentional flexibility in musical interactions should increase as a function of musical experience (see Figure 3.3) – although such experience may also impose culturally specific constraints.

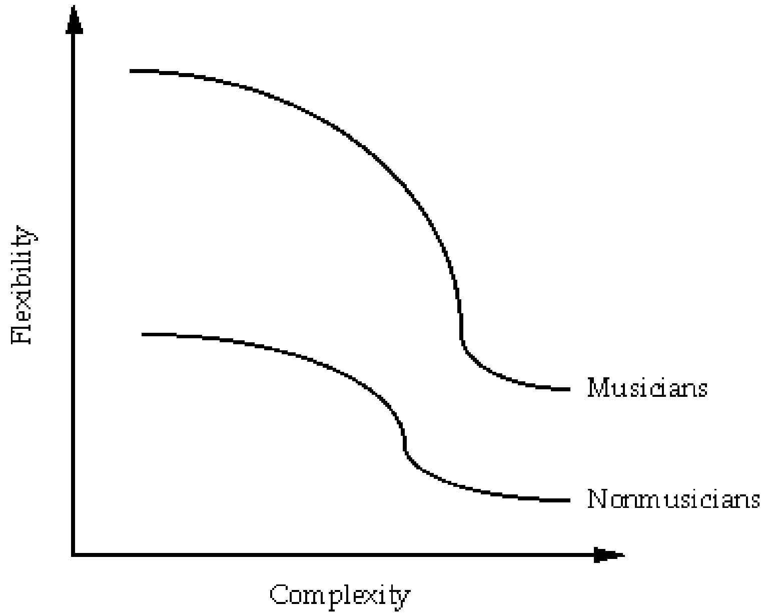


**Figure 3.3:** Hypothetical effects of musicality upon the complexity-flexibility trade-off.

However, differences in the capabilities of musicians and nonmusicians are not merely quantitative, because musicians do not only have a greater *amount* of experience than nonmusicians; their experience also differs in *kind*. The acquisition of musical skill proceeds through specialised training experiences, including those involving musical performance and analytical forms of listening (see Davidson, Howe, & Sloboda, 1997; Deliege & Sloboda, 1997; Sloboda, 1991, 1994).

The qualitative differences in the experiences of musicians and nonmusicians should be evident in how they deal with rhythmic complexity, leading to corresponding differences in their complexity-flexibility trade-off functions (see Figure 3.3). It follows from dynamic attending theoretical proposals about the relationship between expectancy schemes and attending skills that musicians may be not only more flexible overall, but also disproportionately more proficient in the use of metric frameworks. Differences in flexibility should therefore be more evident at low levels of complexity (metrical patterns) than at higher levels (nonmetrical patterns). In addition, the relative robustness of metric frameworks in musicians should ensure that the threshold at which metrical interpretations are no longer feasible is higher for musicians than for nonmusicians. Accordingly, in Figure 3.3 the functions level out after drop-off at lower levels of complexity for nonmusicians than for musicians.

#### 3.3.3.2 Past research into the effects of musicality upon flexibility

Although there is evidence that musicians are able to use metric frameworks in a more sophisticated manner than nonmusicians, skill-based differences in flexibility of attentional strategy have been more difficult to demonstrate. For instance, Jones et al. (1995) manipulated task structure so that under some circumstances it was beneficial to integrate two polyrhythmic streams. whereas under others it was optimal to attend to just one stream (when to-be-detected timing changes occurred in both streams, or a single stream, respectively). Frequency separation between streams was also manipulated to encourage natural tendencies (related to the serial integration region) for either nonprioritised integrative attending (narrow separation) or selective attending (wide separation). Finally, task instructions varied to bias participants to attend either integratively or selectively. It was expected that, due to greater attentional flexibility, musicians would be better than nonmusicians at overcoming natural attending constraints, and hence display disproportionately superior performance when task instructions were consistent with task structure. However, although musicians were more accurate overall in detecting timing changes, qualitatively different attending capabilities did not emerge. Jones et al. (1995, p. 304) summarise their findings as follows: “Whereas all listeners may have some flexibility in attending to such [polyrhythmic] sequences in ways that allow perceptual organization to shift between integrated and streamed configurations, listeners with more musical listening experience appear to be no more flexible in this regard than listeners with little listening experience”. Therefore, Jones et al. (1995, p. 304) conclude that “musical training is not associated with exceptional attentional flexibility”.

Whether or not skill-based differences in rhythmic abilities are detected in empirical research studies seems to be closely related to task variables (Yee et al., 1994). Skill differences have proven to be elusive in investigations using tasks that require recognising (e.g., Bharucha & Pryor, 1986) or reproducing (e.g., Essens, 1986; Essens, 1995; Essens & Povel, 1985; Franks & Canic, 1991; Povel, 1981) basic singlepart patterns, but are more common with relatively demanding tasks such as reproducing polyrhythms (e.g., Summers et al., 1993) or detecting small changes in the timing or pitch of tones embedded in rhythmic contexts (e.g., Jones & Yee, 1997; Smith & Cuddy, 1989; Yee et al., 1994). The cases that show skill-based effects usually reflect quantitative, rather than qualitative, differences in performance by musicians and nonmusicians. That is, similar to the results of the Jones et al. (1995) study, main effects of skill are found, indicating better performance by musicians than nonmusicians, but skill does not often interact in a meaningful way with other factors. This general pattern of results is typically interpreted as indicating that, whereas musicians are more sensitive than nonmusicians to some aspects of temporal structure (e.g., levels of metric hierarchies), they do not approach rhythmic perception and production tasks in a strategically different fashion.

#### 3.3.3.3 Effects of musicality upon attentional strategy

It may be the case that musicians only recruit exceptionally sophisticated strategies when task demands resemble those encountered with *specialised musical experience* more closely than has been customary in experimental investigations of rhythmic behaviour. Musical experience can be considered to be specialised when it results in the acquisition of domain specific skills that qualify an individual for membership in a particular ‘musical community’ (see Swain, 1994), such as populations of composers, soloists, or ensemble performers. It is possible that tasks that have featured in investigations of attentional flexibility have failed to expose skill-based differences because the *generality* of the musical abilities they tap. Even without formal musical training, individuals possess skills related to their latent musical ability and inestimable music listening experience. Skill-based differences in attentional flexibility might emerge when experimental tasks draw on skills associated with those ‘special’ aspects of musical training that provide musicians with greater opportunity and motive than nonmusicians to develop such flexibility. Musical ensembles may provide just the sort of context in which such skills are honed.

It was suggested in Chapter 2 that becoming a beneficial member of a musical ensemble is contingent upon developing flexible prioritised integrative attending skills that allow integrant and aggregate aspects of multipart patterns to be monitored simultaneously. Although individuals without ensemble experience engage in prioritised integrative attending when *listening* to multipart textures, ensemble musicians presumably have greater opportunity and incentive to cultivate attentional flexibility. This is because performers’ interactions with multipart textures necessarily involve *overt* participation, in the sense that they are required to make proactive contributions to the overall sound, as well as respond reactively to feedback about how they are performing their role. Therefore, flexibility that musicians acquire through ensemble experience should enhance their ability to shift attention between different parts in multipart contexts. Qualitative skill differences should be especially likely to surface when experimental tasks demand the use of advanced strategies such as the variety of prioritised integrative attending that characterises ensemble performance.

## 3.3.4 Task demands and attending goals

### 3.3.4.1 Covert versus overt task demands

The process of shifting attention between attuned focal levels in musical events is not only constrained by rhythmic complexity (section 3.3.2) and attending skill (section 3.3.3), but also by demands stemming from the precise nature of the task. Task demands vary with the goals of the interaction between the attender and the event, and the attentional strategies that are best suited to the realisation of these goals. Goals that prescribe covert behavioural responses such as simply listening to, or even memorising, a pattern are generally considered to be less demanding than goals that require overt motor responses such as reproducing a pattern. However, whether the unique demands associated with motor tasks contaminate investigations of rhythmic attending is a methodological issue that has been commented upon but not resolved (see Klein & Jones, 1996).

Resolving metrical ambiguity is perhaps a relatively unformidable goal in itself, as it can presumably be realised sufficiently by a covert attentional shifting strategy. However, certain aspects of the specific task situation may introduce additional attentional requirements that directly affect the demands of the shifting strategy. For instance, additional demands may arise that relate to the mode of attending required to negotiate the rhythmic textural context in which the ambiguity is presented. These include situations where the attender spreads their full attention evenly over a pattern – as when attending to singlepart patterns or employing nonprioritised integrative attending in multipart contexts – and situations where prioritised integrative attending is required in multipart contexts such as ensemble performance. Cases that require attending to singlepart and multipart patterns are considered separately in the next two sections.

### 3.3.4.2 Fully attending to singlepart patterns

When a listener has the opportunity to pay full attention to a metrically ambiguous singlepart pattern, they should be relatively free to shift attention between focal levels associated with the different metric candidates. The pattern in Figure 3.4 and Track 21 is the aggregate pattern that results when two integrant patterns (Integrants 1 & 2) from the multipart pattern in Figure 3.1 are combined. The resultant singlepart pattern has underlying periodicities that are consistent with both a quadruple and a triple metric framework. The beat-level period is the same for both frameworks (600 ms), but the bar-level period varies: 2400 ms for the quadruple framework and 1800 ms for the triple framework. In order to resolve the potential ambiguity, the listener may, upon successive presentations of the pattern, shift attention from the 2400 ms focal period to the 1800 ms focal period. Thus, assuming that the 600 ms pulse is also experienced, they may alternate between quadruple and triple interpretations of the pattern in an attempt to decide which is the most coherent. Povel and Essens (1985) have demonstrated that listeners are able to make reliable judgements about the relative complexity of ambiguous rhythm patterns when interpreted according to different metric frameworks.

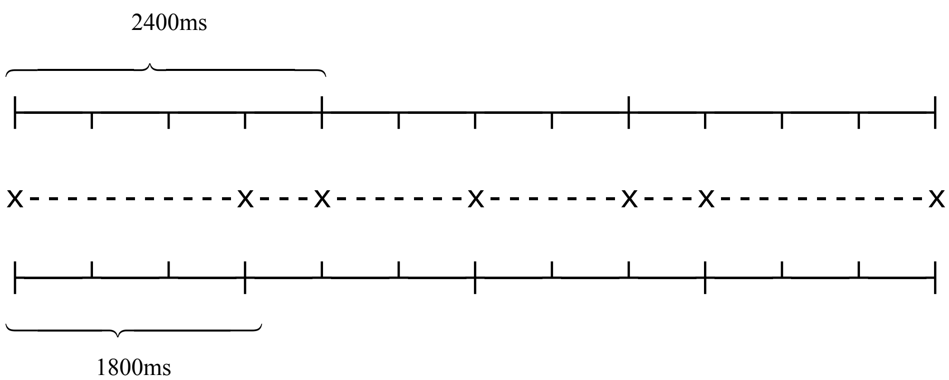


**Figure 3.4:** Metrically ambiguous singlepart pattern with 2400 ms and 1800 ms potential focal periods.

In this example, several factors, which are usually difficult to disentangle, may contribute to the final choice of metric interpretation. Some relevant considerations are formalised in Lerdahl and Jackendoff's (1983) metrical preference rules. Others factors that may influence metric preference include (a) cultural biases (see 3.3.3.1), (b) ratio complexity constraints (see 3.3.1), (c) the relative strength of accents related to events that mark the pulsation levels corresponding to each candidate meter, (d) local contextual effects operative within the pattern itself (e.g., the garden path effects described in section 3.2.3), and (e) the broad, or 'global', context in which the pattern occurs (e.g., the metricality carryover effects described in section 3.2.3 and later in more detail in Appendix 4.5).

Given the impoverished pattern in Figure 3.4, global context effects are not relevant, and it seems reasonable to assume that local context effects are negligible. Furthermore, the application of Povel's accent rules (Povel & Essens, 1985; Povel & Okkerman, 1981; see 1.2.1.3) to the pattern does not reveal any substantive differences between the perceived strength of accents related to events marking the triple and quadruple metric levels. Ratio complexity is likewise an inadequate criterion for distinguishing between metric candidates, since both 4:1 and 3:1 are archetypal ‘simple’ ratios. It is also assumed for present purposes that optimal bar period duration would not play a major role for the pattern in question. Therefore, all other things being equal, the binary bias that has been observed in investigations of rhythmic behaviour (e.g., Bolton, 1894; Fraisse, 1978, 1982; Lerdahl & Jackendoff, 1983; Smith & Cuddy, 1989) suggests that Western listeners would favour a quadruple interpretation of the pattern. It may also be the case that a quadruple interpretation is the more efficient or ‘economical’ solution, given that it results in fewer groups or chunks (corresponding to musical bars) than a triple interpretation (three groups for quadruple versus four for triple).

#### 3.3.4.3 Nonprioritised and prioritised integrative attending to multipart patterns

Shifting attention between focal levels should be more difficult in multipart contexts than in singlepart contexts due to additional attentional demands associated with integrative attending generally. However, the degree to which these auxiliary demands hamper flexibility would depend partly upon the type of integrative attending strategy that is called for by the task situation. Only marginally detrimental effects might be experienced in situations where no single integrant part has priority over any other. In such a case it would be possible to employ the relatively basic nonprioritised integrative attending strategy, whereby integrant patterns that are equal in salience are combined by the attender to form an aggregate pattern. Of course, attentional shifting in these situations may still be constrained by factors that contribute to the perceptual distinction of separate parts in the texture. These factors include differences between parts in terms of frequency separation, timbre, rhythm, and spatial location in the environment (Bregman, 1990; ten Hoopen, 1996; Van Noorden, 1975). Although these factors alone may be quite potent (Jones et al., 1995), even more severe constraints presumably operate upon attentional shifting in task situations where prioritised integrative attending is required (i.e., attention must be divided between a high priority integrant pattern and the aggregate pattern in which it is embedded).

The effects of whether integrative attending is or is not prioritised upon flexibility in attentional shifting may influence how a metrically ambiguous multipart pattern is resolved. The multipart pattern in Figure 3.5 and Track 22 consists of two integrant patterns (Integrants 1 & 2) from Figure 3.1. They are both isochronous, but each defines a different period (2400 ms and 1800 ms for Integrants 1 & 2, respectively). These integrant patterns combine to form the metrically ambiguous aggregate pattern (notated below them) that featured in the previous example. This pattern may either be interpreted according to a quadruple or triple meter, depending upon whether the 2400 ms focal period from Integrant 1 or the 1800 ms focal period from Integrant 2 is preferred (once again assuming a 600 ms beat-level pulse).

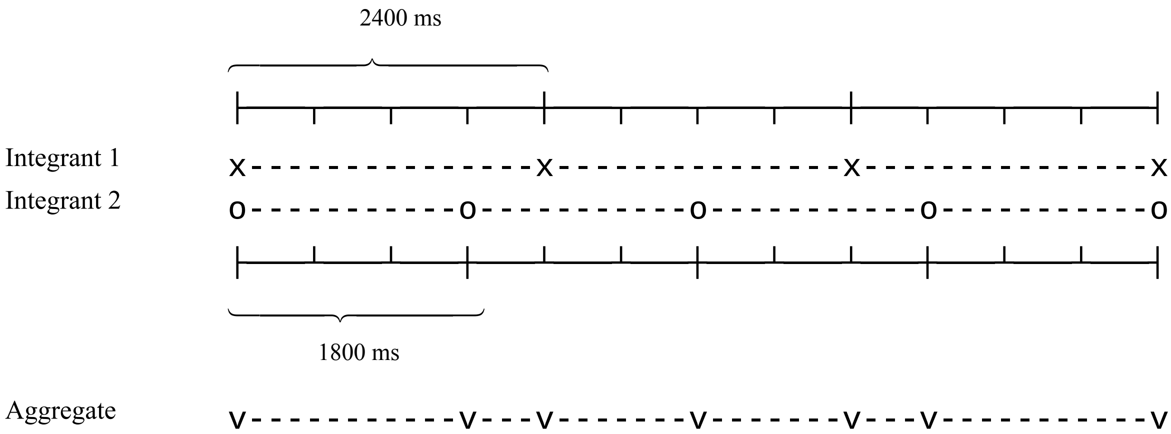


**Figure 3.5:** Metrically ambiguous multipart pattern consisting of isochronous integrant patterns.

Under nonprioritised integrative attending conditions, an attender would be able to pay equal attention to each of the two integrant patterns. Hence, they would be free to alternate between the focal period defined by each integrant pattern in an attempt to find which of these provides the most coherent interpretation of the aggregate pattern. As in the case of the singlepart pattern in Figure 3.4 (and for similar reasons), a quadruple meter interpretation would most likely prevail. However, complications arise when prioritised integrative attending is required.

Prioritised integrative attending would be required in a context like the multipart pattern in Figure 3.5 if the task situation included auxiliary demands specifying that one integrant pattern receives more attention than the other integrant pattern. Such a situation may arise if, for instance, one of the integrant patterns must be performed (i.e., overtly produced) by the attender, or if, in a more musical setting, it is rendered more compelling than the other integrant due to features that interest the attender for some reason (e.g., it carries a tuneful melody). In such circumstances, the higher priority integrant pattern phenomenally can be seen as a figure that stands out against a ground consisting of the low priority integrant pattern (see 1.2.2.4 on polyrhythms). Flexibility in shifting attention between focal periods defined by the higher and lower priority integrant patterns is diminished as a consequence of difficulty in radically switching attentional perspective between figural and ground related aspects of the configuration. A trade-off thus emerges in which increased attention to the higher priority integrant pattern leads to decreased attentional flexibility. This is shown in Figure 3.6, in which the 'prioritisation' (horizontal) axis ranges from nonprioritised integrative attending at the leftmost point to strongly prioritised integrative attending at the rightmost point.

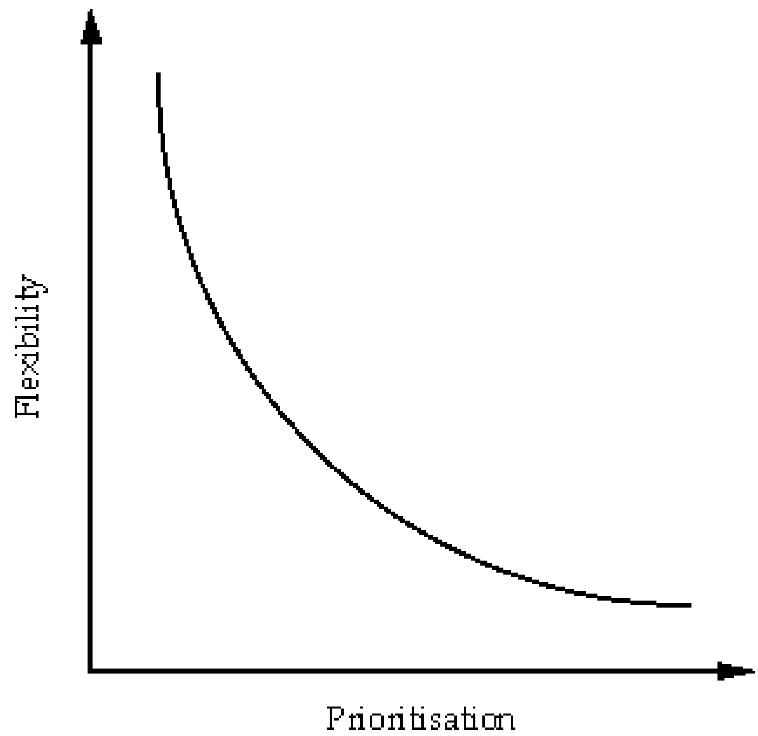


**Figure 3.6:** Hypothetical priority-flexibility trade-off function.

Specialised musical experience, such as that gained in ensembles, should affect this trade-off function, as shown in Figure 3.7. In addition to musicians being capable of greater flexibility overall, flexibility should be limited less severely by increased prioritisation in musicians (especially specialist ensemble performers) than in nonmusicians. Therefore, as noted in section 3.3.3.3, tasks that require prioritised integrative attending should reveal qualitative differences in flexibility between musicians and nonmusicans. Nevertheless, the dynamics of the priority-complexity trade-off most likely encourage preferential use of the higher priority focal period when resolving metrical ambiguity regardless of musicality. In other words, there should be a general tendency for flexibility to be sacrificed in the interest of security.

If Integrant 2 is assigned higher priority than Integrant 1 in the context of the multipart pattern in Figure 3.5, then attention may become anchored firmly to the 1800 ms focal period, thereby discouraging shifts in attending to the 2400 ms focal period. Consequently, the 1800 ms focal period would be favoured as the basis for grouping the events comprising *all* potential aspects of the multipart pattern. The aggregate aspect of the pattern would thus be interpreted according to a triple meter. This contrasts with the quadruple interpretation of the same aggregate pattern which seems to be preferable in the singlepart context discussed earlier, as well as in the multipart context where both integrant patterns are equal in priority. The way in which this hypothetical interpretation of the aggregate pattern is biased by preferential attention to a particular integrant pattern illustrates the schema-like properties of metric frameworks.

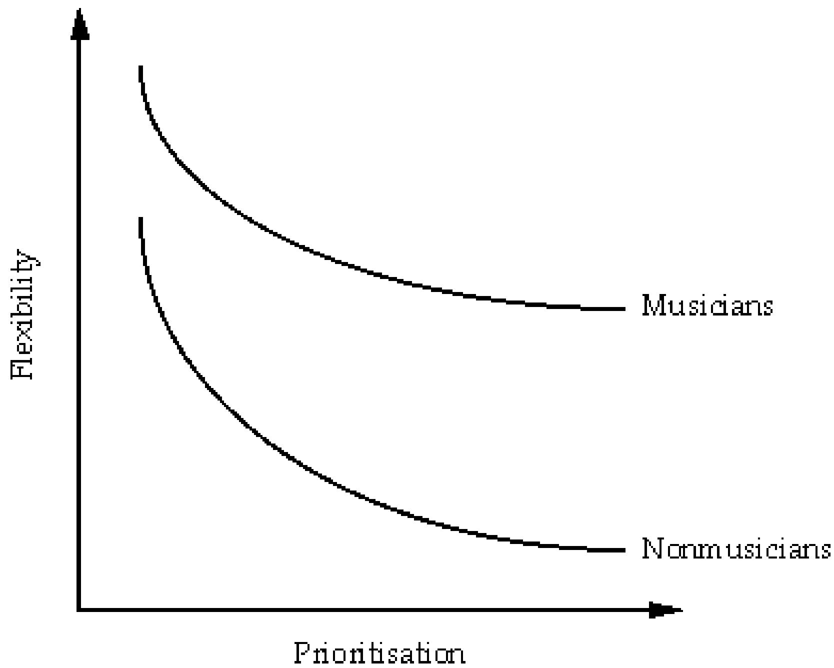


**Figure 3.7:** Hypothetical effects of musicality upon the priority-flexibility trade-off function.

### 3.3.5 Multipart rhythmic complexity and prioritised integrative attending

The above account of the process of generating metric frameworks in the context of a prototypical metrically ambiguous multipart pattern is clearly idealised. The metricality of individual integrant patterns in the example can be considered to be completely unambiguous (one explicitly marks quadruple bar-level pulses while the other marks triple pulses), whereas the aggregate pattern is highly ambiguous (its objective temporal structure suggests equally well an underlying triple or quadruple meter). In an extension of ideas from the dynamic attending approach, it was argued throughout section 3.3.4 that resolution of the ambiguous aggregate structure involves a strategy in which attention is shifted between the conflicting focal periods defined by different integrant patterns. The flexibility with which this strategy proceeds is affected by rhythmic complexity, attender skill, and task demands. Most notably, attentional flexibility is subject to constraints imposed by demands associated with prioritised integrative attending. These constraints presumably become more severe in more complex multipart textures, where integrant patterns may be highly differentiated in terms of rhythmic structure, and where attending goals reach beyond solving metric ambiguity.

In complex multipart contexts, intricacies may be present in the rhythmic structure of individual integrant patterns, as well as in the way in which these integrant patterns mesh to form an aggregate pattern. Integrant patterns vary considerably in terms of rhythmic complexity, or metricality, ranging from those that are prototypically metrical to those that are nonmetrical. Likewise, temporal relationships defined by separate integrant patterns exhibit variability in terms of complexity. For example, a metrical integrant pattern either may or may not best fit the same metric framework as other concurrent integrant patterns or the aggregate pattern in which it is embedded, and nonmetrical integrant patterns may or may not combine to form a metrical aggregate pattern. Thus, *multipart rhythmic complexity* is jointly a function of integrant pattern metricality, and the coherence of the relationship between integrant and aggregate aspects of the pattern. Responses to the Ensemble Performance Questionnaire support this conception of rhythmic complexity in multipart contexts, as indicated by high ‘level of influence’ ratings for the ‘own rhythm’ factor (i.e., complexity of the target integrant pattern) and the ‘overall rhythm’ factor (i.e., aggregate pattern complexity) (see 2.4.3.2.1).

Several possible multi-part structures are given in Figure 3.8, Panels A to C, in order of increasing complexity. The abstract rhythmic notations in this figure correspond to sections of pieces of Western multipart music. Each excerpt has been stripped of pitch and other information included in the original score to make its rhythmic character more evident. The two integrant patterns extracted from each piece were simply collapsed to produce the aggregate patterns notated at the bottom of each panel.

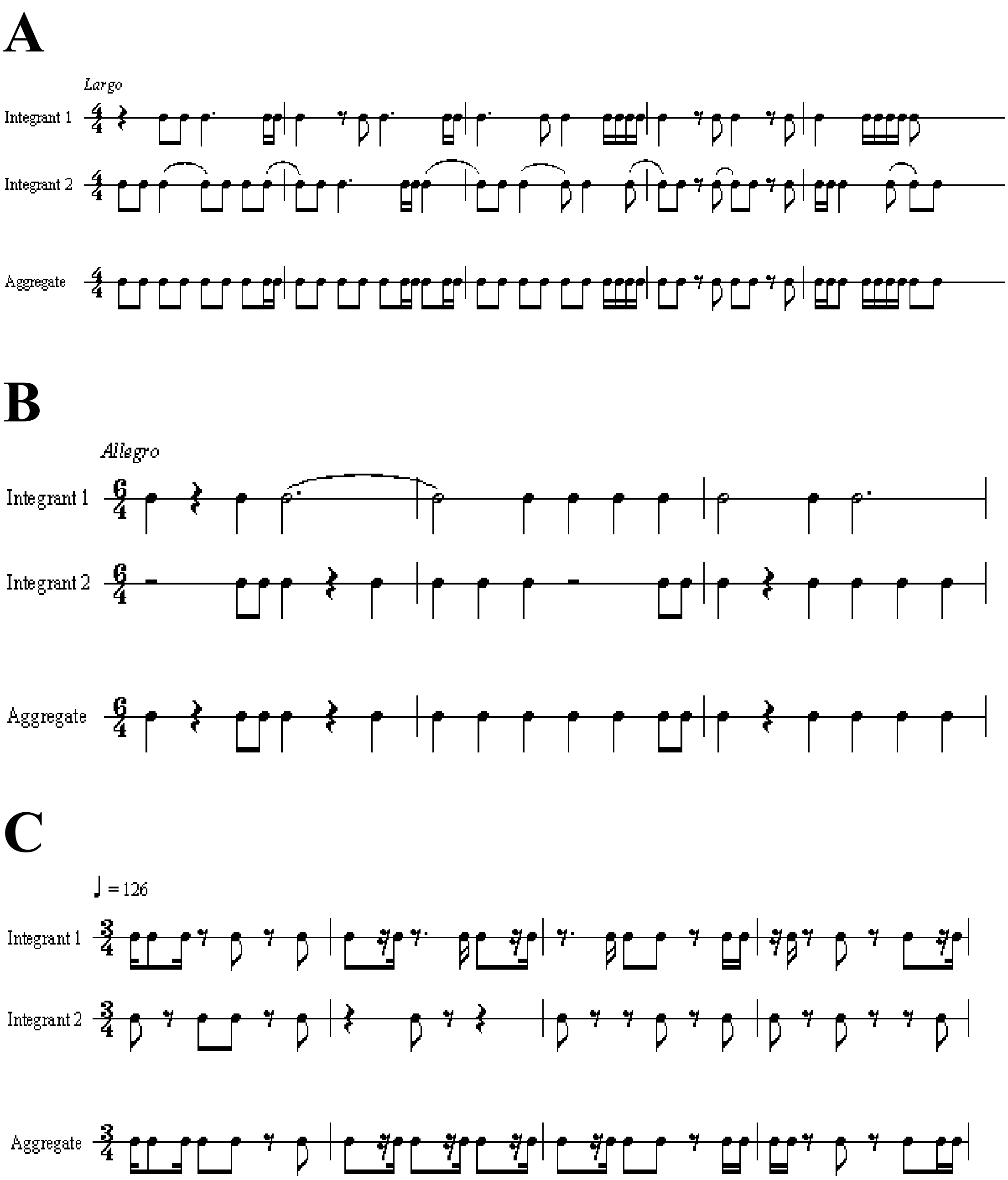


**Figure 3.8:** Multipart rhythmic structures varying in complexity. In Panel A the target integrant pattern (Integrant 1) is metrical and best fits the same meter as the aggregate pattern; in Panel B the target integrant pattern (Integrant 2) is metrical but best fits a different meter to the aggregate pattern; and in Panel C nonmetrical integrant patterns mesh to form a metrical aggregate pattern.

Panel A shows an excerpt from Telemann's *Trio Sonata* in E minor (see Track 23 for presentation of only the rhythm of this excerpt). If *Integrant 1* is nominated as the target integrant pattern, then both target integrant and aggregate pattern aspects fit the same meter: quadruple. Panel B shows an excerpt from the penultimate movement (*Uranus*) of *The Planets* by Holst (see Track 24). If *Integrant 2* is nominated as the target (as it would be for much of the lower half of the orchestra), then target integrant and aggregate patterns best fit different meters (despite the common metric used in Holst's score). The rhythmic cell that occurs twice in the context of Integrant 2 – two short (eighth) notes, a longer (quarter) note, followed by a quarter note rest, and then four more quarter notes – defines a nine beat period, which is inconsistent with the six beat period indicated by the time signature, and indeed the aggregate pattern. Panel C gives the first four bars of the seven bar rhythmic ostinato that underlies the second movement from *Game For Eight* by Blomdahl (see Track 25). If *Integrant 1* is nominated as target, then the target integrant pattern (although notated metrically) is strictly speaking nonmetrical, whereas the aggregate pattern is metrical. The two integrant patterns shown here are only part of the overall rhythmic texture, which is comprised of eight simultaneous integrant patterns in some sections of the movement.

Research by Jones and others has demonstrated the detrimental effects of basic levels of multipart rhythmic complexity upon attentional flexibility under selective attending and nonprioritised integrative attending conditions. This work has revealed that rhythmic complexity affects flexibility uniquely under each different attending condition. Thus, the relationship between multipart rhythmic complexity and attentional flexibility is mediated by attending mode. However, attempts to understand this relationship have not yet extended to contexts where integrative attending is prioritised (see 1.2.3.2.2) – even though such attending is the norm rather than the exception in most multipart musical contexts (see 1.2.2.5). Therefore, the inclusion of prioritised integrative attending conditions should increase the ecological validity of experimental investigations of multipart rhythm.

The unique demands associated with prioritised integrative attending make it a qualitatively distinct attentional strategy to selective attending and nonprioritised integrative attending. It follows that the effects of rhythmic complexity observed with prioritised integrative attending should be distinguishable from those obtained with other modes of attending. Rhythmic complexity may therefore enter into an interactive relationship with the priority-flexibility trade-off shown earlier in Figure 3.6. Accordingly, attentional flexibility in multipart contexts should covary with combined demands arising through (a) multipart rhythmic complexity and (b) the degree to which integrative attending is prioritised (see Figure 3.9).

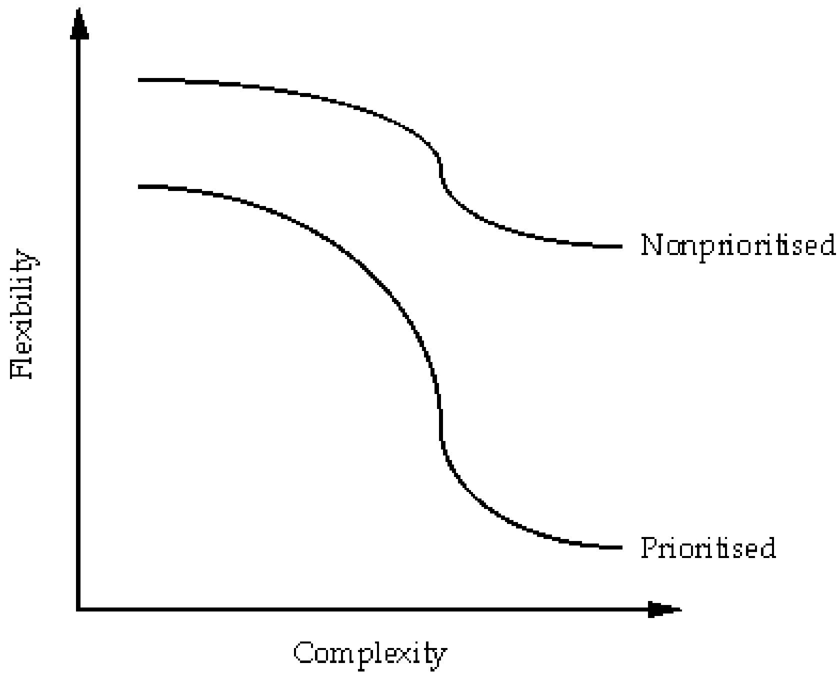


**Figure 3.9:** Hypothetical effects of prioritisation upon the complexity-flexibility trade-off function.

Figure 3.9 shows the effects of attending mode and multipart rhythmic complexity (a product of both the complexity of individual integrant patterns and the complexity of their relationship to an aggregate pattern) upon attentional flexibility. Separate complexity-flexibility trade-off functions are plotted for nonprioritised and prioritised integrative attending. It can be seen that increases in both rhythmic complexity and prioritisation are accompanied by decreases in flexibility: each trade-off function has negative slope and the value of the ordinate is lower for prioritised than for nonprioritised integrative attending. However, as the steepness of the slope of each trade-off function is determined *jointly* by attending mode and multipart rhythmic complexity, an interaction occurs. When multipart rhythmic complexity is low, attending mode has only a small effect upon flexibility, whereas the effect of attending mode is large when complexity is high.

The proposed interactive effects of complexity, musicality, prioritisation, and their effects upon flexibility have only been described so far. Some principles that might underlie the proposed effects are considered below. Specifically, the dynamics of the trade-off between complexity and attending mode on one hand, and flexibility on the other, are elucidated by considering theoretical accounts of how task structure and task demands generally influence the availability and use of an individual's attentional resources.

# 3.4 Attentional resource allocation in prioritised integrative attending

## 3.4.1 Attentional capacity and timesharing

The proposition advanced above that attentional flexibility trades off with a variety of factors is founded upon the assumption that attention is limited. This assumption is central in *capacity theories* of attention (see Wickens, 1980, 1984), which generally propose that there exist absolute limits to the capacity of the cognitive system's attentional resources. The term 'resources' is used here to refer to task-specific sensory, perceptual, cognitive, and motor processes, and the neural assemblages in which these processes are based.

The major implication of the limited capacity assumption is that, as mental workload increases, more resources are consumed and consequently less resources are available. Accordingly, in multiple task situations (i.e., when two or more activities are carried out concurrently), a difficulty-performance trade-off is often observed in which performance on a secondary task suffers as the difficulty of the primary task is increased (see Wickens, 1980).

Although it was originally proposed in capacity theories that attentional resources reside in a single reservoir or pool (Broadbent, 1958; Kahneman, 1973; Knowles, 1963; Moray, 1967), it is currently held that the cognitive system is comprised of multiple resource pools (Wickens, 1980, 1991). These resource pools are differentiated in terms of the types of activity they support and the stages of processing during which they are tapped (Smyth et al., 1987; Wickens, 1980, 1991). Separate resources are demanded by activities that involve different operating modes (e.g., verbal versus spatial), and different modalities of input (e.g., visual versus auditory) and output, or response (e.g., manual versus vocal). Likewise, separate resources are called upon during different stages of processing, such as 'early' perceptual/cognitive processing (e.g., encoding) versus 'late' response-related processing (e.g., retrieval and motor programming). It has been argued that multiple task performance can proceed relatively unimpaired when component tasks each tap exclusive pools of resources (Wickens, 1984). For example, Allport, Antonis, and Reynolds (1972) found that musicians could simultaneously sight-read piano music and shadow a spoken message without sacrificing performance accuracy on either task.

The term 'timesharing' is used widely to describe the concurrent performance of multiple tasks (e.g., Barber, 1988; Wickens, 1984, 1991). The appropriateness of this term is perhaps most striking in situations where the temporal relationship between tasks is crucial. Multipart musical interactions therefore exemplify instances in which timesharing must take place in a very literal sense. However, it is appropriate to consider such interactions in terms of timesharing multiple tasks only under certain integrative attending conditions. Multipart interactions that require nonprioritised integrative attending are viewed best as a single task. On the other hand, interactions that require prioritised integrative attending can be characterised as multiple tasks, specifically dual tasks, in which one component task involves paying attention to a target integrant pattern, and the other component involves paying attention to the aggregate pattern. Processing the target integrant can be considered to be the primary task, in which case processing the aggregate pattern is the secondary task. This order of precedence is more evident when prioritisation is strong than when it is weak. Indeed, in some contexts where weakly prioritised integrative attending is required, the aggregate pattern may become primary, and the target integrant pattern secondary (e.g., when sections of a vocal choir have many members, who are each highly familiar with their part, the ensemble will benefit most from these individuals attending to the overall choral sound rather than their own voice).

### 3.4.2 Resource demands in prioritised integrative attending

In order to gain a fuller understanding of how resource theory applies to prioritised integrative attending, it is useful to consider separately the various processes that underlie attending to each multipart aspect: target integrant and aggregate. In general, the processes involved in prioritised integrative attending include tracking target and complementary integrant patterns, grouping together elements both within and between integrant patterns, forming memory representations, and retrieving from memory various sorts of information relevant to the multipart interaction at hand. The nature of these processes, or sub-skills, varies according to whether the interaction involves performing or only listening (i.e., observing). For example, memory retrieval requirements related to target integrant patterns are typically greater when performing than when observing. Next in sections 3.4.2.1 and 3.4.2.2, resource demands that arise during both performance and observation are discussed in relation to their impact upon processing target integrant and aggregate patterns, respectively. Then, in section 3.4.3.3, the demands associated with combining these task components are discussed. These sections are quite detailed, as the specific processes that underlie prioritised integrative attending have not been identified in previous research. Indeed, it is surprising that music educational criteria for assessing performance skills typically focus upon competence at solo performance, rather than the sub-skills involved in prioritised integrative attending, given that a large proportion of the world's music is for ensembles.

#### 3.4.2.1 Resource components of target integrant pattern processing

##### *3.4.2.1.1 Encoding: Tracking and representation formation*

The encoding processes involved in attending to a target integrant pattern include tracking the pattern as it unfolds, and forming an internal representation of its structure. Tracking and representation formation are components of both performance and observation: performers and audience members typically have some recollection of the quality of a performance. For the performer, tracking involves monitoring the sound they are producing, i.e., the target integrant pattern. Feedback about one's own productions is received through auditory, visual, and proprioceptive (tactile and kinaesthetic) channels (Gabrielsson, 1999). For the listener, proprioceptive channels play a less significant role in target integrant pattern encoding because observing does not necessarily involve overt production. In line with the dynamic attending view that expectancy schemes guide attending (Jones, 1982, 1990), it is assumed here that metric frameworks can be used to direct tracking and representation formation.

##### *3.4.2.1.2 Retrieval processes in performance*

The overt nature of performing makes it necessary to direct behaviour 'on-line' (i.e., during performance) in accordance with *performance goals* established prior to actual performance. Performance goals reside in memory as idealised mental representations of the patterns constituting a particular musical piece (Palmer, 1997; Rideout, 1992). These representations are formed in the course of preparing the piece for performance. During such preparation, *performance plans* that prescribe how to realise performance goals are also acquired (Drake & Palmer, 2000; Sloboda, 1982). Performance plans serve as strategies for transforming representations of ideal patterns into sound (see Gabrielsson, 1999). In actual performance, the performer retrieves from memory a representation of the goal pattern and its related performance plan. These are subsequently used to direct motor processes involved in pattern production (Palmer, 1997; Shaffer, 1985). Phenomenally, retrieval is experienced as a form of *auditory imagery* (Halpern, 1992; Intons-Peterson, 1992; Walters, 1989). The performer imagines hearing the goal pattern prior to overt pattern production. Support for this goal-directed account of musical performance comes from the introspections of expert performers (see Blum, 1977; Clynes, 1987; Menuhin, 1976; Moore, 1953) and techniques in music education (see Green, 1986; Heuser, 1998).

Performance goals and plans are relied upon to the greatest extent in situations where a musical script is used during the preparation of a piece for performance, but then discarded before the actual performance. In such situations, retrieval is initially costly in terms of resource consumption because the piece must be performed literally 'from memory'. However, retrieval costs may eventually be reduced when the piece becomes highly familiar and the processes associated with its performance are more or less automated. Standing in contrast to performing from memory is sight-reading, wherein performance goals and plans are absent because the piece is unfamiliar and the musical script is not made available until the actual performance. Although sight-reading obviously does not involve accessing an idealised representation of a pattern before it is produced, other information relevant to producing the pattern must be retrieved from memory.

It is customary for competent sight-readers to visually scan sections of the script beyond the point corresponding to what they are currently producing, in order to prepare for the production of upcoming events (see Gabrielsson, 1999). When 'reading ahead', the performer engages pattern recognition processes aimed at identifying melodic or rhythmic figures that have been encountered previously, or bear close relation to familiar figures. Recognition of these familiar figures facilitates the priming of motor control programs that drive their execution (Gruson, 1988). A rarely discussed, but nevertheless interesting, feature of the pattern recognition processes that occur when sight-reading is their cross-modal character: comparisons are made between *visual* representations of patterns in the notated script and mental representations of familiar *auditory* patterns. In order to facilitate such pattern matching, visual patterns notated in the musical script are encoded and transformed into auditory images through a process of inner hearing, or *audiation* (Campbell, 1989; Brodsky, Henik, Rubinstein, & Zorman, 1998; Gordon, 1988). Although audiation is distinct from the mental replaying of memorised patterns (Heuser, 1998), both are forms of auditory imagery.

The retrieval processes that characterise performing from memory and sight-reading can be distinguished in several ways. One means of differentiation is to focus upon how each activity is distinct in terms of the *access operations* used to recover memory representations: performing from memory involves *recall*, whereas sight-reading involves *recognition*. Another approach is to address differences in the *type of memory representation* that is accessed. Performing from memory can be considered to be an *episodic memory* task (see Crowder, 1993a; Humphreys, Bain, & Pike, 1989; Tulving, 1982, 1985). The performance goals and plans referred to when performing from memory are originally consolidated during practice sessions geared towards the preparation of a particular piece. Thus, they are the result of experience in a specific context. On the other hand, sight-reading can be characterised as a *procedural memory* task (see Humphreys et al, 1989; Tulving, 1985). The pattern recognition processes and motor control programs engaged during sight-reading refer to generalised, or abstract memory representations (see Pressing, 1988) that defy description by performers (Gabrielsson, 1999).

Distinguishing between performing from memory and sight-reading on the basis of access operations (recall versus recognition) and the nature of memory representations (episodic versus procedural) implies that the processing resources involved in retrieval may vary according to performance situation. The cross-modal aspects associated exclusively with sight-reading add further weight to this claim.

#### *3.4.2.1.3 Retrieval processes in observation*

Like performance, observation is characterised by situation specific variations in resource requirements. Although the retrieval of motor control programs is usually not necessary when only listening, other forms of memory retrieval become relevant in cases where the listener is familiar with either the piece being presented, or the musical genre to which it belongs. The type of memory processes recruited in these situations depends upon the degree to which the listener is familiar with the music.

Familiarity varies not only as a function of whether or not a musical piece or genre has been encountered previously by the listener, but also with the conditions under which previously-encountered music was experienced. *Active listening* conditions in which an individual concentrates attention upon structural and expressive details of the music obviously engenders greater familiarity than *passive listening* conditions where the music is unattended or only peripherally attended. For example, greater familiarity will ensue when an individual listens actively as a music critic at a concert they must review, than when they listen passively (if at all) as a shopper taking a ride in a department store elevator. The differences in memory representation that result from such differing listening modes have been framed in terms of explicit versus implicit memories.

The term *implicit memory* is used properly to describe situations where information residing in memory surreptitiously affects task performance(see Underwood & Bright, 1995). Thus, it involves unintentional memory *retrieval* processes of which the individual is unaware. In contrast, the term *implicit learning* is used when information is *encoded* unintentionally and without awareness. The distinction between implicit memory and implicit learning has become muddied in the music cognition literature. To accommodate the existing conceptual confusion, the blanket term *implicit processes* will be used here to cover any encoding or retrieval that occurs implicitly. The term *implicit memories* will be used to refer to actual mental representations. Although the encoding of the represented information may or may not have occurred implicitly, its retrieval is necessarily implicit.

*Explicit memories* are formed through the use of deliberate encoding or memorisation processes on the part of the attender. Once explicit memories are stored, their retrieval "entails intentional or conscious recollection of previous experiences" (Schacter, Chiu, & Ochsner, 1993, p. 159). Episodic memories for musical patterns, which arise through active listening, can be considered to be instances of explicit musical memory (Crowder, 1993a). The episodic aspects of performing from memory are also assumed to be under the control of explicit memory. As is the case of performing from memory, the retrieval of explicit memories resulting from active listening may be characterised as a process of auditory imagery.

The (unintentional) retrieval of implicit memories results in "the influence of a previously memorised piece of information on a task without the explicit or deliberate attempt to recall the memory" (Underwood & Bright, 1995, p. 10). Implicit processes have been used as explanatory principles in demonstrations of priming and the effectiveness of subliminal messages (Underwood & Bright, 1995). These phenomena have also received attention in music cognition research. Priming effects have been found in studies that address the perception of musical elements including melody (Crowder, 1993a), harmony (Bharucha, 1987; Bharucha & Stoeckig, 1986), tonality (Krumhansl, 1990), and timbre (Crowder, 1989). Furthermore, subliminal effects of film music have been observed on the interpretation of visual scenes (Boltz, Schulkind, & Kantra, 1991; Thompson, Russo, & Sinclair, 1992), and anecdotal claims have been made that subliminal messages are operative in other musical genres (e.g., heavy metal). Although there is not a long tradition of research on implicit music memory, work indicating that implicit memory mediates everyday listening has been described by Crowder (1993a) and Gaudreau and Peretz (1999).

Many everyday listening experiences take place passively. Crowder (1993a, p. 134) has proposed that implicit memory processes contribute to the appreciation of certain music structural features by musically trained and untrained individuals alike:

> "The more ecologically general kinds of melody memory may occur implicitly, when we cannot express the retention verbally but when it nevertheless affects our musical processing. The re-entry of a fugue theme, the occurrence of a leitmotif, or the development section of a remembered sonata-movement subject may all be examples of implicit music memory. The appreciation of these devices may not be restricted to musicologists".

Of course, implicit processes characterise performance as well as observation. For instance, the procedural aspects of sight-reading rely upon implicit memories.

#### *3.4.2.1.4 Classifying performance and observation according to retrieval demands*

The performance- and observation-based musical activities discussed above are classified in Figure 3.10 according to the types of retrieval processes they involve. Figure 3.10 shows a space for specifying type of musical interaction according to three dimensions. The vertical dimension represents a continuum of activity from observation to performance. The horizontal dimension represents memory representation types ranging from implicit/procedural memories to explicit/episodic memories. The diagonal dimension represents access operations ranging from recognition to recall. The direction of all arrows represents increasing resource demands. Performance- and observation-based activities are represented as regions within the musical interaction space defined by these three dimensions. Thus, Figure 3.10 can be used to gauge the relative retrieval demands of various musical activities.

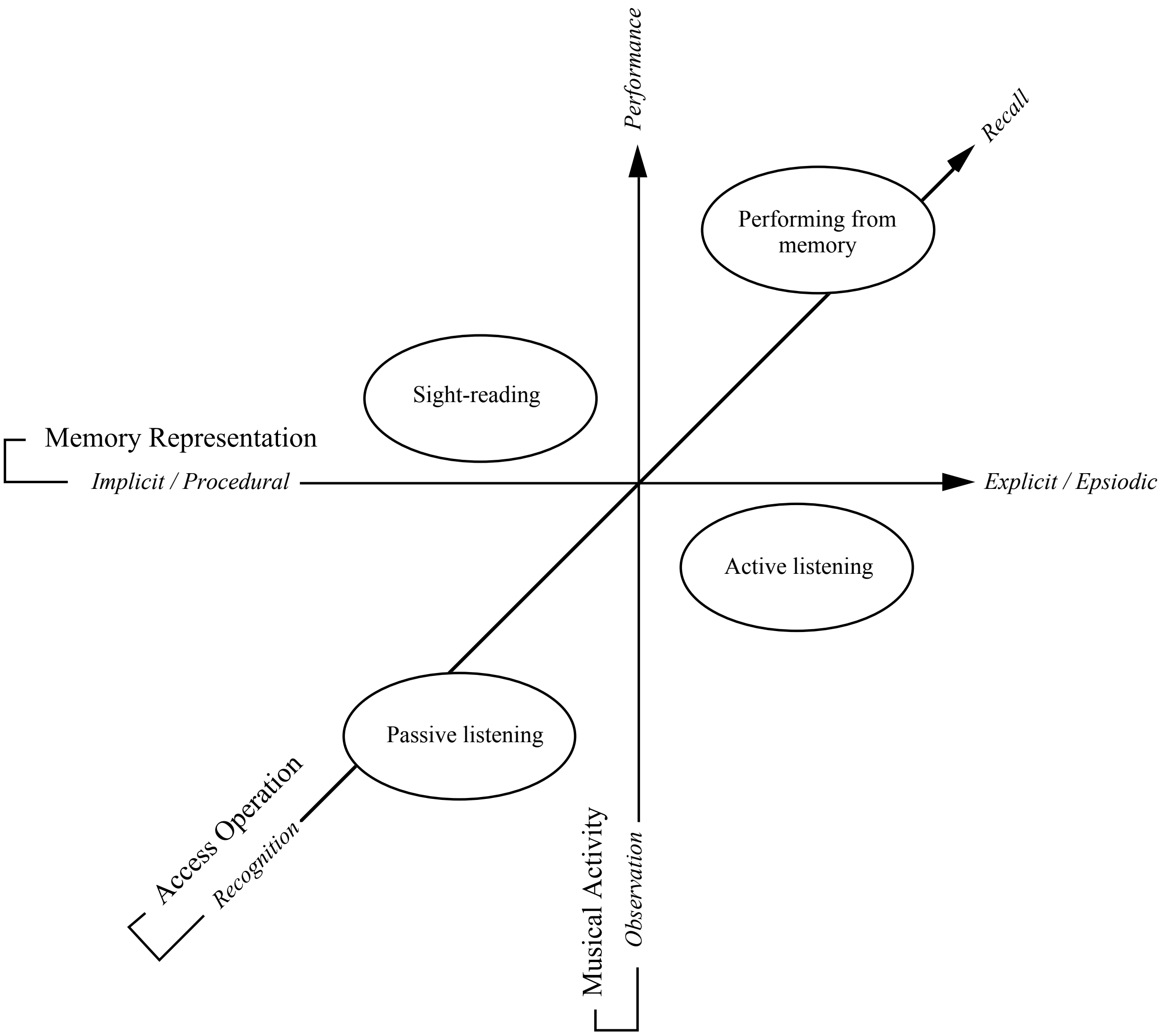


**Figure 3.10:** Classification of performance- and observation-based musical activities according to the access operations and types of memory representation that characterise their underlying retrieval processes.

In Figure 3.10, the two components of retrieval processes – access operations and memory representation type – are neither perfectly aligned nor orthogonal. Their oblique relationship embodies two assumptions. First, although explicit/episodic memory representations are typically accessed through recall, and implicit/procedural memory representations are usually associated with recognition, this is not always the case. Second, performance-based activities are more likely to have higher recall demands than observation-based activities. Another assumption underlying this classification scheme is that the performance-observation, recall-recognition, and explicit/episodic-implicit/procedural dimensions are not strictly bipolar. For example, there exist asymmetries such that performance presupposes observation, but not vice versa. Indeed, it is assumed that all the musical activities under consideration in this discussion involve observation, and are affected by recognition access operations and implicit/procedural memory representations. Therefore, the activities are more accurately differentiated in terms of the degree to which these baseline characteristics are supplemented by reliance upon overt performance, recall, and explicit/episodic memories.

The activities described earlier - performing from memory, active listening, sight-reading, and passive listening - can all be placed in the classification scheme in Figure 3.10. Performing from memory is heavily dependent upon recalling explicit/episodic memories. Active listening (to familiar music) is moderately dependent upon recalling explicit/episodic memories (it occupies a lower position than performing from memory on the recognition-recall dimension). Sight-reading relies mainly upon recognition and implicit/procedural memories. Passive listening relies almost exclusively upon recognition and implicit/procedural memories (it occupies a low position on all three dimensions). Other activities can also be accommodated. For example, performing from a rehearsed script can be viewed as intermediate to performing from memory and sight-reading, while active listening to unfamiliar music can be considered as intermediate to active listening to familiar music and passive listening.

##### *3.4.2.1.5 Auditory imagery and metric frameworks*

Despite having different profiles in terms of access operations and memory representation type, the retrieval processes underlying performing from memory, sight-reading, active listening, and passive listening are all assumed to be guided by metric frameworks. In other words, metric frameworks serve as schemas in all of these performance- and observation-based retrieval contexts. Although the schematic effects of metric frameworks have not been examined directly in each of these specific musical contexts, the memory and cognition literature contains numerous reports of schemas affecting tasks with similarly varied retrieval demands. For example, it has been found that schemas activated during retrieval profoundly affect recall in explicit/episodic memory paradigms (e.g., Linton, 1982) and both recall and recognition in implicit/procedural memory tasks involving pattern recognition (e.g., Hyman & Frost, 1975), the use of artificial grammars (Reber, 1967) and motor control (see Schmidt, 1975).

Clearly the schemas activated in these various contexts differ considerably: some are high-level knowledge structures acquired through specific experiences, whereas others are lower-level perceptual and motor tendencies that are most likely innate. This reflects the distinction between conceptual and sensorimotor schemas that work together to guide music perception (Francès, 1988). Nevertheless, examples of single schematic constructs operate across a range of diverse situations. One such construct that has been observed in musical contexts is the *tonal hierarchy* (i.e., a rule-based schema that specifies perceived pitch relations relative to one referent pitch, the tonic). The tonal hierarchy has been found to affect performance on explicit tasks that require judgements of how well a tone fits a previously established tonal context (Krumhansl, 1983; Krumhansl & Shepard, 1979), as well as more implicit tasks requiring detection of altered tones that are either consistent or inconsistent with the surrounding tonal context (Krumhansl & Castellano, 1983). Metric framework generation may likewise transcend specific task demands to operate as an all-purpose retrieval mechanism.

Although metric frameworks guide retrieval across a broad range of activities, whether their generation is proactive or reactive (see 3.2.4) is determined by context specific factors. It is currently assumed that these factors relate directly to the degree to which retrieval processes demanded by the situation involve auditory imagery. This close relationship between auditory imagery and metric framework generation is suggested by claims that they are mutually reliant upon the motor system. A tradition of linking imagery of thought with motor processes can be traced to Piaget (1970, 1971, 1977) and Hebb (1958). Early applications of related ideas to musical behaviour were made by Jaques-Dalcroze (1915, 1921) and Seashore (1938/1967). Seashore (1938/1967, p. 139), for example, proposes that the fundamental requisites for rhythmic behaviour include "auditory imagery and motor imagery, that is, the capacity for reviving vividly in representation the auditory experience and the motor attitudes respectively".

Recent empirical findings support the existence of links between auditory imagery and the sensation of motor activity, or *kinaesthesis* (Intons-Peterson, 1992). Brodsky et al. (1998, p. 241) present evidence that "Inner Hearing is an articulatory kinesthetic-like cue linked to the phonological system". Similarly, Heuser (1998) reports results that highlight the complementarity of auditory imagery and motor skills.

Furthermore, there is physiological evidence that both metric framework generation and auditory imagery are mediated by the association motor cortex (Todd, 1996). Therefore, it seems reasonable to postulate that metric framework generation is a rudimentary form of auditory imagery that paves the way for more sophisticated imagery (with pitch and loudness, in addition to rhythmic, components) by raising the level of activation in the association motor cortex. However, metric framework generation does not necessarily lead to the evocation of rich auditory images, for example, when listening to unfamiliar music. It is assumed here that rich auditory imagery relies upon metric frameworks being generated proactively, rather than reactively.

It was suggested earlier that rich imagery is associated with active retrieval processes (e.g., recall-based access operations and explicit/episodic types of memory representation) and overt motor behaviour (see 3.4.3.1.2). Hence, musical activities such as performing from memory, sight-reading, and active listening to familiar music are characterised by auditory imagery to a greater extent than activities like passive listening and active listening to unfamiliar music. Moreover, the postulated relationship between richness of auditory imagery and metric framework generation has implications for the metric foundations of retrieval in these different contexts. The retrieval processes involved in performing from memory, sight reading, and active listening to familiar music are likely to be guided by proactive metric framework generation, whereas passive listening and active listening to unfamiliar music involve reactive metric framework generation.

#### 3.4.2.2 Resource components of aggregate pattern processing

So far the discussion has centred upon processing the target integrant aspect of multipart patterns during prioritised integrative attending. Attending to the aggregate aspect involves the encoding and retrieval processes associated with attending to the target integrant pattern, plus demands related to tracking complementary integrant patterns, grouping together elements belonging to target and complementary patterns, and forming an internal representation of the aggregate structure. As in target integrant pattern processing, retrieval demands may arise if the attender recalls familiar versions of the aggregate structure during the interaction. Retrieval may also be associated specifically with a complementary integrant pattern, for example, if a performer recognises a particular section of another's part that serves as a cue to execute a particular action in their own part (e.g., introduce an expressive timing deviation).

The resource demands of aggregate pattern processing differ from those of target integrant pattern processing primarily in terms of the grouping process that combines elements from different integrant patterns. The process will be referred to here as *trans-integrant grouping*. It is assumed here that, like tracking, representation formation, and retrieval processes, trans-integrant grouping is ideally guided by metric frameworks: just as meter provides a basis for grouping elements within singlepart rhythm patterns, it can be used in multipart contexts as a common frame of reference for grouping together elements distributed over several integrant patterns.

It is also assumed that trans-integrant grouping is achieved through either switching or parallel processing strategies. Switching strategies involve shifting attention from target to complementary integrant patterns, whereas parallel processing strategies involve attending simultaneously and continuously to target and complementary integrant patterns (with a higher proportion of attentional resources devoted to processing the target integrant pattern).[9] A distinction has been drawn between these strategies in discussions of timesharing in general multiple task contexts (e.g., Barber, 1988), and both have been implicated in explanations of specific auditory temporal phenomena such as auditory streaming (Jones, 1976; Michon & Jackson, 1984) and the perception of polyphonic versus homophonic musical textures (Leman, 1995). Clearly, however, regardless of whether trans-integrant grouping proceeds via switching, parallel processing, or a mixture of the two, it requires considerable attentional flexibility.

#### 3.4.2.3 Combined target integrant and aggregate processing

In the present analysis, prioritised integrative attending has been broken down into component sub-skills including tracking, trans-integrant grouping, representation formation, and memory retrieval processes that vary in terms of access operations (recall/recognition) and represenation type (implicit-procedural/explicit-episodic). Examining the resource demands of target integrant pattern processing (section 3.3.2.3.1) and aggregate pattern processing (section 3.3.2.3.2) reveals that potentially they have a majority of these processing routines in common, such that attending to target integrant and aggregate patterns relies upon common pools of resources: those employed in tracking, those employed in representation formation, and those employed in memory processes. It is also possible that different sub-skills rely upon common resources. Even tracking and memory retrieval, which seem at first glance to be very different types of sub-skill, may share resources. Wickens (1980) has reviewed a large number of dual task investigations where tracking tasks (both auditory and visual-manual) are paired with various memory-based tasks. From his review, Wickens (1980, p. 246) concludes that “Memory processes

[9] See 7.2.7.1 for a more detailed discussion of switching and parallel processing strategies.

and tracking apparently depend on some common resources for their performance because the performance-difficultly tradeoff is invariably present".[10]

A central claim in multiple resource theories is that the availability of resources is more restricted when two tasks impinge upon the same resource pool (or pools) than when they tap different resource pools (Wickens, 1980, 1991). Therefore, resource theory predicts a trade-off in prioritised integrative attending: as more resources are allocated to target integrant processing, less remain for aggregate patterns processing, and vice versa. In other words, processing one multipart pattern aspect can steal resources from the task of processing the other aspect.

In contexts that demand prioritised integrative attending, resources are allocated to each component of the dual task of attending to the target integrant pattern, on the one hand, and the aggregate pattern, on the other, in proportion to the degree of prioritisation required. This proposal follows from another general assumption of resource theory, which states that "when two tasks make simultaneous calls on the same resource reservoir, resource allocation is necessary and this will be decided in terms of task priorities, incentives, and so forth" (Barber, 1988, p. 131). Therefore, under conditions where integrative attending is strongly prioritised, a large portion of resources will be devoted to the target integrant pattern, thereby leaving fewer resources free for processing the aggregate pattern than would be available under nonprioritised integrative attending conditions. As prioritisation weakens, less resources need to be allocated to processing the target integrant pattern, and more become available for processing the aggregate pattern.

Resource theory generally assumes that resource allocation is a conscious process that requires effort by the attender. In fact, Wickens (1991, p. 4) argues that "resources *are* the mental effort that is invested to improve performance" [emphasis added]. To evaluate the validity of this claim in the context of the resources involved in prioritised integrative attending, it is necessary to consider how effortful are tracking, trans-integrant grouping, representation formation, memory retrieval, and the underlying process of metric framework generation. In the literature on attention, mental effort is usually conceived of in terms of automaticity of processing.

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[10] Perhaps this conclusion is overly general and should be treated with caution, as it may gloss over some important differences based on the type of tracking and memory task.

## 3.4.3 Automaticity and effort in prioritised integrative attending

### 3.4.3.1 Automaticity in temporal information processing

Many researchers (e.g., Hasher & Zacks, 1979; Posner & Snyder, 1975; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977) have discussed the distinction between *effortful* (sometimes called *controlled* or *deliberate*) processing operations, which require conscious attention in order to proceed, and *automatic* processing operations, which are conducted unconsciously. Several specific criteria have been identified as useful in distinguishing automatic from effortful processes. It is generally accepted that automatic processes: (a) are initiated unintentionally; (b) are not under conscious control; (c) do not arouse awareness of their operation; (d) are resistant to suppression; (e) run to completion once they have been activated; (f) do not require mental effort; (g) do not interfere with other processes; (h) are unaffected by other processes; (i) develop with practice; and (j) do not result in the storage of new information without additional processing. Hasher and Zacks (1979) propose supplementary criteria that apply to a specific class of innate automatic processes: they are unaffected by practice and display only minimal individual differences. Failure to meet these criteria does not necessarily disqualify a processing operation from being considered automatic. Currently popular views conceptualise *automaticity* as a continuous dimension, rather than as one of two discrete categories – automatic and effortful (Hasher & Zacks, 1979; Kahneman & Chajzyck, 1983; Cohen, Dunbar & McClelland, 1990). In accordance with this conception, the term 'automatic' will be used here to refer to processes that are high in automaticity (i.e., require relatively little effort) and the term 'effortful' will be used to refer to processes that are low in automaticity.

The notion of automaticity has gone in and out of favour during the evolution of theories that address temporal information processing (see Hasher & Zacks, 1979; Jackson, 1985; Michon & Jackson, 1984; Miller, Hicks, & Willette, 1978; Zacks et al., 1984; Zimmerman & Underwood, 1968). To account for this lability, Jackson (1985) points out that there is a great deal of variability in the definition of temporal information in investigations of automaticity. Nevertheless, the majority of previous evaluations of the automaticity of temporal information processing have viewed time only in terms of ordinal relations, such as serial succession in word lists. The real time and continuous aspects of temporal processing have been neglected. This limits the degree to which their conclusions apply to behaviours such as prioritised integrative attending in musical rhythmic contexts.

Although the automaticity of temporal information processing in musical contexts where prioritised integrative attending is required has not been submitted to rigorous empirical evaluation, a modest attempt was made to address this issue in the EPQ study described in Chapter 2 (sections 2.3.4.3 & 2.4.3.3). The results provided an indication that ensemble performers believe that, although prioritised integrative attending is usually effortful, it may be characterised by elements of automaticity under some circumstances. This suggests that evaluations of automaticity in which skilled behaviours such as prioritised integrative attending are assumed to be unidimensional may be misleading. Indeed, as Underwood and Bright (1995) point out, most skilled behaviours are viewed more appropriately as hierarchically organised complexes of component sub-skills, wherein differential degrees of automaticity are associated with each hierarchical level.

In section 3.4.2, it was claimed that metric frameworks may play a role in guiding the component sub-skills of prioritised integrative attending - tracking, trans-integrant grouping, representation formation, and memory retrieval. Thus, the generation of metric frameworks can be viewed as a relatively low-level prioritised integrative attending sub-skill. Underwood and Bright (1995, p. 23) state, in a discussion of the development of automatic processes, that "(a)ttention may be directed initially at the control of the low-level components, but as practice is increased these components are automatised and attention can be released for higher-level activities". In order to ascertain whether this applies to the relation between metric framework generation and the higher-level sub-skills it supports, evidence for automaticity in metric framework generation is now examined.

### 3.4.3.2 Automaticity in metric framework generation

#### *3.4.3.2.1 Rhythmic complexity and automaticity*

The models of musical rhythmic behaviour reviewed in Chapter 1 do not explicitly address the automaticity of metric framework generation. Nevertheless, the characterisation by these models of expectancies and metric pulsations as spontaneous responses to certain temporal structures implies that they may be generated automatically (see Boltz, 1993; Parncutt, 1994a; Jones, 1976; Krumhansl, 1992).

However, it has been argued that expectancy formation, and hence metric framework generation, is not always effortless. Narmour (1989) identifies both conscious and subconscious expectations. Likewise, other researchers have distinguished between top-down knowledge-based expectancies and bottom-up perceptual expectancies that exhibit characteristics of effortful and automatic processes, respectively (Bharucha, 1987; Boltz, 1993; Francès, 1988; Jones, 1990; Schmuckler, 1989). The distinction between proactive and reactive metric frameworks may reflect this contrast to some degree. Even so, Jones (1990, p. 213) implies that some level of attentiveness is required even for reactive metric framework generation: "one or several expectancies will arise only if a listener has abstracted some invariant which permits generative activity in a specified context. Conversely, if no invariant has been abstracted, or if a listener is not attending, then this rationale implies that no generative activity should occur".

Rhythmic complexity affects expectancies, and thereby influences the automaticity of metric framework generation. Martin (1972, p. 506) claims that "Expectancies that are confirmed should make any kind of perceptual processing easier, whereas expectancies that are violated should make processing harder". This is consistent with Michon and Jackson's (1984) assumption that if automatic processes are interrupted, controlled processes will be engaged. Accordingly, Martin (1972, p. 488) states quite explicitly that, whereas metrical patterns are processed automatically, nonmetrical patterns call for an effortful mode of processing:

> "since rhythmically patterned sounds have a time trajectory that can be tracked without continuous monitoring, perception of initial elements in a pattern allows later elements to be *anticipated* in real time… Perception of concatenated sounds [where no hierarchical structure obtains, i.e., nonmetrical patterns], on the other hand, would seem to require continuous attention".

However, a more fine-grained comparative analysis of the structure of metrical and nonmetrical patterns reveals that the issue of automaticity in processing is not clear-cut. This becomes apparent when the figural aspects of a pattern are distinguished from the metric aspects (see Bamberger, 1991; Essens, 1995; Handel, 1998).

#### *3.4.3.2.2 Figural and metric aspects of rhythm*

Figural aspects refer to small groups of pattern elements, sometimes termed 'tone clusters', Elements within a cluster are grouped due to their close temporal proximity. According to Jones (1976), such clusters are picked up by the listener through use of a temporal segmentation process that is a variety of chunking. Individual tone clusters often consist of short ‘runs’, wherein elements follow each other in quick succession, which are punctuated by one or more ‘gaps’, or silent intervals (Royer & Garner, 1970).

It is likely to be the case that the figural groups in both metrical and nonmetrical patterns are processed by a combination of processes that occupy both ends of the automaticity spectrum. Processing runs of elements involves encoding frequency-of-occurrence information (i.e., the number of elements that occur within a run). Hasher and Zacks (1979) argue that such information is processed relatively automatically. On the other hand, noting the location of gaps is a matter of gathering information about spacing (i.e., where gaps occur in a series of runs). Jackson (1985) has shown that information about spacing requires effortful processing. Thus, in both metrical an nonmetrical patterns, individual figural groups should be processed each with a similar degree of automatic and effortful processes. It is when the location of figural groups relative to one another is processed that metrical patterns enjoy advantages. Metric frameworks provide a basis for specifying automatically the relative location of individual figural groups in metrical patterns. On the other hand, this element of automaticity is lacking in nonmetrical patterns, and, hence, other strategies must be used to link figural groups, which are “perceived against ordinal, ongoing time” (Handel, 1992, p. 498). These strategies include organisation, clustering, and mnemonic devices. According to Hasher and Zacks (1979), such processes are effortful. It is assumed here that even if the attender were to proactively generate a metric framework, and attempt to use it to specify the temporal structure of a nonmetrical pattern, both generation and fitting processes would require considerable effort.

The distinction between figural and metric aspects of rhythm is highlighted by the results of studies that examine the ability of individuals to produce notations of rhythm patterns. It has been shown that when individuals (both children and adults) are asked to notate metrical rhythms patterns (with symbols of their choice), some represent metric aspects, whereas others represent figural aspects (Bamberger, 1980; Smith, Cuddy, & Upitis, 1994). This research exposes considerable differences in strategy use even in the case of metrical patterns. These differences seem to be related primarily to the degree of musical training, with trained individuals producing metric transcriptions and untrained individuals favouring figural representations. These findings suggest tentatively that without training individuals focus on figural aspects of patterns, and that proficiency in the use of metric frameworks develops with practice. Such practice with metrical patterns should, it seems, eventually allow effortful processes that encode cluster inter-relationships to give way to more automatic grouping processes based on meter.

However, there are problems with using notation paradigms exclusively to investigate the figural and metric aspects of understanding rhythm. Smith, Cuddy, and Upitis (1994) have shown that individuals identified as figural drawers do (irrespective of their musical training) have metric understanding, as measured by reproduction and synchronisation tasks. Furthermore, sensitivity to periodic structures underlying rhythm patterns has been demonstrated in infants (Allen, Walker, Symonds, & Marcell, 1977; Demany, McKenzie, & Vurpillot, 1977; Chang & Trehub, 1977; Trehub & Thorpe, 1989; Trevarthen, 1999) and European starlings (Braaten & Hulse, 1993; Hulse, Humpal, & Cynx, 1984). So, even though infants and starlings are not renowned for strict accuracy in producing metric structure, they are able to perceive it. Therefore, it may be necessary to distinguish between different levels of metric understanding: one implicit or 'procedural' (where the individual only knows how to use metric frameworks), the other explicit or 'declarative' (where the individual knows how to describe, as well as use, metric frameworks). Indeed, it has been suggested that focal attending, which is related to the experience of metric pulsations in the dynamic attending approach, develops without the individual's awareness. Jones and Boltz (1989, p. 471) claim that "(f)ocal attending is a tacit, how-to skill that is implicitly acquired".

#### *3.4.3.2.3 Metric framework generation and the automaticity criteria*

Returning to the question of the automaticity of metric framework generation, there is difficulty in determining how well the process itself satisfies the automaticity criteria outlined in section 3.4.3.1. This is because the criteria were formulated in contexts quite different to those in which metric frameworks are operative, and have not been rigorously applied in studies of metric framework generation. Nevertheless, some general correspondences may be noted.

The spontaneous manner in which metric framework generation can take place, and the fact that untrained musicians appear to use frameworks, but do not represent them in notation and are incapable of describing them, indicates that metric frameworks are sometimes initiated unintentionally, are not under conscious control, and do not arouse awareness of their operation (see criteria a, b, &c). These properties are more characteristic of reactive, than of proactive, metric framework generation. Proactive metric framework generation satisfies automaticity criteria relating to the tenacity of automatic processes (criteria d & e). For instance, the robustness of frameworks generated proactively (as evidenced by metricality carryover effects and the metric violation threshold) indicates that they are resistant to suppression.[11]

The fact that metric frameworks (both reactive and proactive) accompany a wide range of complex behaviours may be taken as evidence, albeit indirect and weak, that their generation requires minimal mental effort, does not interfere with other processing (so long as the information can be accommodated by the active framework), and is to some degree unaffected by other processes (criteria f, g, & h). Whether or not the frameworks themselves develop with practice (criterion i) is unclear, but the efficiency with which they are utilised improves with practice. Finally, the notion that metric frameworks only provide a guide for attentional processes is consistent with the idea that they do not lead to storage of new information in the absence of other processing (criterion j). Of course, the identity of requisite additional processes depends upon the component sub-skills demanded by the context. The automaticity of prioritised integrative attending is considered in the next section.

#### 3.4.3.3 Automaticity in tracking, trans-integrant grouping, representation formation, and retrieval processes

Whether the process of tracking is automatic or effortful may depend upon the attender's goals. Mental effort may be required to the extent that it is necessary to focus attention upon expressive qualities of complementary integrant patterns (e.g., timing deviations or melodic ornaments). In support of this, the results of the EPQ (see 2.4.4.1) suggest that picking up information about balance, intonation, and tempo may be automatic, whereas detecting subtle details relating to rhythmic cohesion, phrasing, and articulation may be more effortful.

The degree to which trans-integrant grouping is effortful presumably depends upon factors such as how highly prioritised is the target integrant pattern and how coherent is the relationship between target and complementary integrant patterns. It is assumed here that trans-integrant grouping is effortful when prioritised integrative attending is required.

[11] Doubts may be raised about the appropriateness of 'running to completion' as a criterion against which to evaluate metric frameworks, as their recursive structure allows an infinite number of lawful termination points. However, the tendency for the pulse sensations to continue up to the next bar-level pulsation following the final element of a metrical pattern can be taken to suggest that this criterion is satisfied.

Given that implicit learning leads to stable representations of different types of information in a wide variety of contexts (Underwood & Bright, 1995), it is assumed here that representation formation is not effortful.

Memory retrieval processes in prioritised integrative attending vary according to whether the attender is a performer, or merely an observer. It was argued in section 3.4.2.1.4 that performance is demanding in terms of both recall and recognition, whereas observation is less demanding in terms of recall. Hasher and Zacks' (1979) proposal that recall involves more effortful processing than recognition suggests that memory processes will be more effortful in performance than in observation. It was also argued that auditory imagery and the reinstatement of the conditions during which performance goals were formulated are significant aspects of recall in performance contexts. Hasher and Zacks (1979) claim that such imagery and mnemonic techniques are effortful. Halpern and Zatorre (1996, p. 436) more or less agree with this view of imagery, stating that "while image generation seems effortless, maintaining the trace to perform tasks requires sustained mental effort". Less effortful will be those elements of prioritised integrative attending that rely upon implicit learning and memory (e.g., bottom-up pattern recognition processes).

#### 3.4.3.4 The relationship between metric frameworks and other prioritised integrative attending sub-skills

The automaticity profile of prioritised integrative attending appears to be complex, with each sub-skill potentially residing at one of many possible different points along the automaticity continuum, depending upon the attender's skill, pattern complexity, and attending goals. It may be the case that metric framework generation falls closer to the automatic end of the continuum and tracking, trans-integrant grouping, and memory retrieval (but not representation formation) are more effortful. The relative ease with which metric frameworks are generated may enable them to lend attentional resources to, rather than steal resources away from, other relatively effortful prioritised integrative attending sub-skills. *Metric frameworks automatically provide a default attentional scheme for resource allocation. They make tracking, trans-integrant grouping, and memory retrieval less effortful through their role in guiding attending*. By invoking metric frameworks, the attender to a certain extent relinquishes responsibility for consciously deciding how to deploy their attentional resources. Thus, metric frameworks regulate attending somewhat like an automatic pilot control mechanism regulates aircraft flight.

Autopilot systems make the task of controlling an aircraft less effortful for human operators by automatically maintaining altitude, preset course, and steadiness. The challenge for autopilot systems is to achieve these ideals in the face of fluctuations in surrounding environmental conditions. However, autopilots do not completely take over the task of controlling the aircraft. The human operator must be ready to intervene in the presence of dangerously large deviations from a planned trajectory. Often these interventions need only be minor, but in the event of an emergency the automatic pilot surrenders to manual control.

Metric frameworks function analogously in the sense that their underlying expectancy schemes are like preset courses that specify ideal attentional trajectories. Furthermore, like autopilot systems, metric frameworks take command of some of the processes involved in the regulation of temporal interactions. They run unobtrusively to control attention in a manner that promotes the efficiency of other processing operations demanded by the situation. Fewer demands should be placed upon attentional resources when target integrant patterns are metrical than when they are nonmetrical. Therefore, when target integrant patterns are metrical, there should be relatively greater availability of resources for the tracking, trans-integrant grouping, representation formation, and memory retrieval activities involved in processing aggregate patterns. However, when target integrant patterns are nonmetrical (or turbulent), tracking, trans-integrant grouping, and other sub-skills associated with aggregate pattern processing are curbed by restricted resource availability.

### 3.4.4 Issues in applying traditional resource theory to prioritised integrative attending

In the above discussion, it was argued using concepts borrowed from traditional resource theory that target integrant and aggregate processing compete for limited resources because they rely upon common sub-skills. This account implies that any deficit in aggregate pattern processing will be due to insufficient resources, so, in a situation where a nonmetrical target integrant pattern is embedded within an aggregate pattern, deficits in aggregate pattern processes would be attributed to a scarcity of resources. However, using traditional resource theory as a basis for understanding prioritised integrative attending may be problematic. As Klapp et al. (1985, p. 825) point out, traditional resource theory "assumes summation in the dual task of resource demands of component tasks, but does not address the effects of relative timing". Therefore, the majority of multiple task investigations in nonmusical domains employ experimental paradigms in which the temporal relationship between component tasks is not as crucial as it is in prioritised integrative attending. For example, if each component task in a dual task context consists of a series of processing steps, real time aspects of the way in which these steps align with one another are rarely considered. Hence, it is exceedingly difficult to find task demands that resemble trans-integrant grouping in investigations of multiple task performance other than those that address polyrhythmic behaviour.

One erroneous prediction that follows from traditional resource theory is that making the component tasks distinctively different necessarily leads to better dual task performance. It has been demonstrated that this is not the case in studies using polyrhythmic stimuli. Klapp et al. (1985, Experiments 1 & 2) have shown, using stimuli consisting of two streams each presented in a distinct modality (auditory and visual), that perceptual accuracy is greater when the separate streams are similar in temporal structure, than when they are dissimilar. Furthermore, production accuracy deteriorates when polyrhythmic streams (presented in the auditory modality) are made more distinctive in terms of pitch and spatial location (Klapp et al., 1985, Experiment 3; see also Jones et al., 1995). Klapp et al. (1985, p. 826) interpret these findings to indicate that similarity between component tasks engenders an "integrated perception of the situation, and leads to better performance". Thus, the findings of such multiple task investigations where the temporal relationship between concurrent tasks is nonrandom challenge accounts of resource allocation that ignore the effects of temporal factors.

Recent advances in resource theory have introduced concepts that can be used to account for the temporal sensitivity of resource allocation. Two such concepts are 'task compatibility' and 'interference'.

### 3.4.5 Compatibility of target integrant and aggregate processing

Wickens (1989, 1991) has proposed that even when each component of a dual task taps the same pool/s, the availability of resources for each task may vary as a function of how similar, or compatible, the tasks are along spatial and temporal dimensions. Compatible tasks utilise resources from a common pool such that processing operations associated with each task can coevolve harmoniously. Damos (1991, p. 105) discusses multiple task situations where "some dimension or aspect of one stimulus can be used to predict a dimension or aspect of the second stimulus". She concludes that "As the correlation between the stimuli or the dimensions increases, the amount of information to be processed effectively decreases, and task performance should approximate the corresponding single task levels" (Damos, 1991, p. 105). Thus, compatibility produces situations where "a common mental set, processing routine, or timing mechanism can be activated in service of the two tasks" (Wickens, 1991, p. 23).

Early support for the task compatibility hypothesis comes from a study by Chernikoff, Duey, and Taylor (1960). Using an experimental procedure consisting of a tracking task where the progress of two separate moving targets had to be followed, they found that performance was superior when the control dynamics of each target were the same than when they were different. Perhaps even more relevant are the findings that polyrhythmic performance is better when streams have narrower pitch separation (spatial compatibility) and simpler ratio relationships (temporal compatibility) (see 1.2.3.4 & 3.4.4). Summers (1989) provides a detailed discussion of such temporal constraints on the concurrent performance of motor tasks.

In prioritised integrative attending, the degree to which the task of attending to a target integrant pattern is compatible with the task of attending to an aggregate pattern depends, in part, upon the coherence of the relationship between the temporal structure of each multipart pattern aspect. Thus, task compatibility is related to the concept of temporal coherence (Jones and Boltz, 1989; see 1.2.3.2.2). Earlier it was proposed that coherence in multipart musical rhythm is a matter of multipart rhythmic complexity, and that multipart rhythmic complexity is often determined by the degree to which target integrant and aggregate patterns are interpretable within the same metric framework (see 3.3.5). Therefore, the task compatibility hypothesis leads to the prediction that prioritised integrative attending should be more efficient when integrant and aggregate aspects of a multipart pattern best fit the same metric framework.

### 3.4.6 Interference effects in prioritised integrative attending

Incompatible tasks can be distinguished from compatible tasks (see Heuer, 1996). Incompatible tasks elicit processing routines that are mutually discordant. According to Wickens (1991, p. 24), "differences between these routines lead to interference, confusion, and conflict".

Interference-based explanations of dual task decrements posit that degraded performance is a consequence of the *disruption of processing*, rather than the *scarcity of resources* for processing (see Neumann, 1996; Wickens, 1989, 1991). *Outcome conflict* has been identified as one source of such disruption (Navon, 1984, 1985; Tsang, Shaner, & Vidulich, 1995). The outcome conflict hypothesis states that interference is caused by an overabundance of processing resulting when one task has “outputs, throughput, or side-effects that are harmful to the processing of the concurrent task” (Navon, 1985, p. 7). Such interference effects have been observed in investigations of multiple task behaviour in contexts other than music. For example, it has been found that a primary task that imposes heavy demands on attentional resources (mathematical problem solving) can impair performance on a secondary task that involves schema acquisition (verbal comprehension) (Sweller, Chandler, Tierney, & Cooper, 1990).

Multipart musical rhythmic contexts where a nonmetrical target integrant pattern is embedded within a metrical aggregate pattern may be viewed as analogous to the mathematical-verbal dual task employed by Sweller et al. (1990). The nonmetrical target integrant pattern is demanding by virtue of its complexity, and attention to the (metrical) aggregate pattern involves schema acquisition to the extent that it requires the generation of metric frameworks. If the analogy holds true, the process of generating a framework with which to interpret the aggregate pattern should be disrupted by attention to nonmetrical patterns. An interference-based account of this effect holds that either (a) dealing with substantial expectancy violations perturbs metric framework generation, or (b) attending to nonmetrical patterns involves a processing routine that is incompatible with metric framework generation. Thus, interference is related to expectancy violation and fine-grained analytic attending in the dynamic attending approach (Jones, 1982, 1990; Jones & Boltz, 1989).

Disturbances to aggregate pattern processing are not limited to multipart contexts where target integrant patterns are nonmetrical. Such disturbances may also occur in situations where both the target integrant and the aggregate pattern are metrical, but best fit a different meter. It is assumed here that the aggregate pattern processing is extremely sensitive to the processes that underlie attending to the target integrant pattern. Therefore, if metric framework generation accompanies target integrant processing, then the active framework will be used to interpret the aggregate pattern, even if it is not the best-fitting framework.

In polyrhythmic production studies, difficulty is commonly found in tapping two conflicting rhythms (one per hand) without one pattern dominating the organisation and performance of the other (Klapp, 1979; Klapp et al., 1985; Peters, 1977). This temporal locking of separate behavioural sequences is usually attributed to response related motor constraints (Klapp et al., 1985). However, in prioritised integrative attending, attentional constraints are more germane than pure motor constraints. Interestingly, studies that directly compare performance on polyrhythmic perception and production tasks (e.g., Klapp et al., 1985) have found that behaviour on these tasks is qualitatively similar, suggesting that the constraints are not purely motor. Attentional constraints presumably operate because the optimal processing scheme is different for each sequence. Limits on resources permit only a single scheme to be engaged, and hence the attender is constrained to choose between competing schemes. It is assumed here that the dominant scheme is determined partly by task priorities. Therefore, the dominance of target integrant meter should become more pronounced as target integrant pattern priority increases.

Furthermore, it is assumed here that the degree to which target integrant meter is dominant is influenced by whether the metric framework generation is proactive or reactive. Proactively generated metric frameworks are more robust (due to their top-down nature) than frameworks generated reactively. Consequently, it should be the case that aggregate pattern encoding is affected more strongly by proactively generated target integrant metric frameworks than by reactively generated frameworks. Therefore, any biasing effects of target integrant meter should be more pronounced in performance than in observation. This tendency should produce greater benefits to target integrant processing in performance than in obervation because metric framework generation should be relatively resistant to interference in performance.

This benefit needs to be offset against costs to aggregate pattern processing in situations where the target integrant pattern and the aggregate pattern best fit different meters. In such situations, the process of generating the metric framework associated with the target integrant pattern will meet with interference when attention is directed to the ill-fitting aggregate structure. This is because the attentional trajectories defined by the dominant metric framework – i.e., the framework associated with the target integrant pattern – are not ideal for capturing information contained in the complementary integrant pattern. It is highly likely that the elements in complementary integrant patterns that are important for specifying aggregate pattern structure occur at weak locations in the metric framework associated with the target integrant pattern. These structurally important complementary events are missed (or not adequately processed) due to relatively low attentional focus at weak metric locations (see Large & Jones, 1999). Attempts to recover these neglected events (e.g., by accessing echoic memory, Neisser, 1967), or to prepare for their recurrence, will be disruptive to processing and, thereby, interfere with ongoing attentional processes. Such interference is consistent with the outcome conflict hypothesis described above.

## 3.5 Summary

At the opening of this chapter, the attentional mechanisms underlying metric frameworks were described in terms of expectancies and schemas (see 3.2). This reinforces the notion (developed through Chapters 1 and 2) that metric frameworks serve ecologically adaptive preparatory functions in musical rhythmic interactions. In particular, metric frameworks facilitate multipart rhythmic interactions by enabling processing efficiency, thereby allowing the attentional flexibility that is requisite for behaviours such as prioritised integrative attending.

The effects of several factors upon attentional flexibility in both singlepart and multipart rhythmic contexts were considered in section 3.3. These include rhythmic complexity (metricality), attending skill (musicality), and task demands and attending goals (prioritised versus nonprioritised integrative attending). Figure 3.11 summarises the hypothesised effects of these factors, and their interactions, upon attentional flexibility. It can be seen that flexibility decreases with increasing rhythmic complexity, decreasing musicality, and increases in the degree to which integrative attending is prioritised. Furthermore, these factors interact such that the effects of musicality are greater at low, than at high, levels of complexity, and the effects of both musicality and complexity are greater at high, than at low, levels of prioritisation.

An explanation of these effects was offered based on attentional resource allocation in multiple task contexts in section 3.4. Resource demands in prioritised integrative attending were addressed by identifying several of its component sub-skills, including tracking, trans-integrant grouping, representation formation, and memory retrieval processes. It was argued that metric framework generation plays an important role in prioritised integrative attending by providing, more or less automatically, an attentional scheme that guides these component sub-skills. On the other hand, when the process of metric framework generation is disturbed, resource allocation becomes inefficient, more effortful, and largely incompatible with flexible attentional strategies that foster prioritised integrative attending.

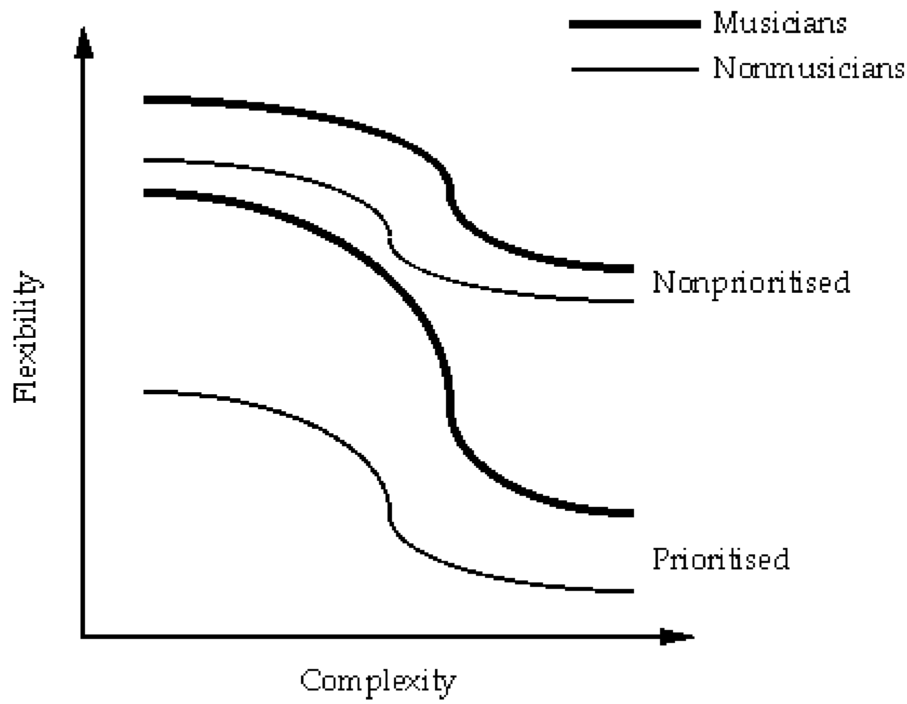


**Figure 3.11:** Hypothetical effects of multipart rhythmic complexity, musicality, and prioritisation upon attention flexibility.

The resource-based account of prioritised integrative attending in multipart rhythmic contexts suggests that concepts such as task compatibility and interference effects contribute to a fuller understanding of the mechanisms by which target integrant and aggregate pattern aspects are processed simultaneously. When target integrant and aggregate patterns best fit the same metric framework, prioritised integrative attending should proceed relatively smoothly because both aspects of the multipart pattern are temporally compatible. Resources associated with each aspect are employed consistently. However, when target integrant patterns are nonmetrical (i.e., if considered in isolation), the processing operations that they enlist are incompatible with aggregate pattern processing, and therefore produce interference.

Some degree of interference should also occur when both target integrant and aggregate patterns are metrical, but best fit different meters. The strength of interference effects in such situations should depend partly upon whether the task requires metric frameworks to be generated proactively (via top-down processes) or reactively (via bottom-up processes). Interference should be greater when metric frameworks associated with the target integrant pattern are generated proactively (e.g., when performing from memory) than when they are generated reactively (e.g., when listening to unfamiliar music). This is because bias to interpret the aggregate pattern according to the ill-fitting framework belonging to the target integrant pattern is stronger in the former case than in the latter.

The subsequent chapters of this dissertation test specific predictions derived from these general hypotheses in empirical studies of both singlepart (Chapter 5) and multipart (Chapter 6) musical rhythm.

# CHAPTER 4

## METHODOLOGICAL ISSUES IN THE EMPIRICAL INVESTIGATION OF METER

This chapter addresses issues relating to investigating empirically the use of metric frameworks in singlepart and multipart rhythmic contexts. The discussion centres upon the importance of finding suitable indices of the efficiency with which rhythm patterns are both processed and represented. Several new singlepart and multipart experimental paradigms are identified, and the methodological elements shared by these paradigms are described in a general method section.

## 4.1 Introduction

The theoretical underpinnings of the hypothesis that metric frameworks facilitate prioritised integrative attending in multipart musical rhythmic contexts have now been given. It was argued that the generation of metric frameworks enhances processing efficiency and allows greater attentional flexibility. Therefore, when prioritised integrative attending is required, the concurrent *processing* of target integrant and aggregate patterns should proceed more efficiently when target integrant patterns are metrical than when they are nonmetrical, and, if target integrant patterns are metrical, when they fit the same meter as the aggregate pattern (see 3.3.5, 3.4.5, & 3.4.6). It was also claimed that interdependent mental *representations* formed for target integrant and aggregate patterns are more efficient when based on metric frameworks (see 1.2.2.5 & 1.2.3.4). This representational efficiency should allow information about the temporal structure of these multipart pattern aspects to be organised coherently in memory.

A strong case was made that both *processing efficiency* and *representational efficiency* are important determinants of multipart rhythmic behaviour, albeit for different reasons (see 1.2.3.4). The benefits of processing efficiency relate mainly to the promotion of the real-time encoding and retrieval of temporal information, whereas representational efficiency is beneficial because coherent memory organisation allows a greater amount of information to be retained and makes this information more readily accessible for use in modifying future behaviour. This distinction suggests that meter has dual roles. On one hand, metric frameworks act as dynamic attentional schemes that guide real time processing. On the other hand, their properties as hierarchical templates allow temporal information to be represented efficiently in memory.

It has been shown that failure to distinguish between processing and representational efficiency leads to incomplete theoretical models and conceptual confusion when interpreting the results of behavioural research (see 1.2.3.3). However, the independence of these two types of efficiency is yet to be demonstrated empirically. In order to tease these apart, and, in doing so, test the hypotheses formulated in Chapter 3, experimental procedures that address the interaction of listeners and performers with the complex multipart textures that characterise real music need to be developed.

## 4.2 Demonstrating processing and representational efficiency experimentally

### 4.2.1 Distinguishing between processing and representation

The models of rhythmic behaviour reviewed in earlier chapters have been assessed by others in empirical studies employing standard perceptual and production-based tasks. The majority of these studies use one or more of the following paradigms: (a) *recognition memory tasks* where the participant is exposed to a rhythm pattern, and then must decide whether subsequently presented test patterns (usually a target and several distracters) are the same or different to the exposed pattern; (b) *reproduction tasks* where the participant is exposed to a pattern that they must memorise and reproduce by tapping at some point after the exposure item has ended; (c) *synchronisation tasks* where the target pattern is presented cyclically and the participant is required to tap along in synchrony; (d) *detection tasks* where the participant is required to indicate if or when a target event (e.g., a temporal or pitch deviation) occurs during the presentation of a pattern.

As noted in Chapter 1, findings yielded by the above empirical methods – usually that behaviour related to metrical patterns is more accurate than nonmetrical behaviour – are interpreted according to the proclivities of the particular model under evaluation. Representational models attribute such findings to the efficiency with which metrical patterns are represented symbolically in memory, whereas procedural models emphasise the efficiency of metrical processing routines (see 1.2.3). Hence, data that are essentially the same have the potential to be interpreted variously. This is problematic because, although processing and representational efficiency are typically highly correlated, this is not necessarily the case. It is conceivable, for instance, that efficient representations can be arrived at through inefficient processing strategies. Maze learning provides an example in a nonmusical domain.

If an individual were dropped blindfolded at the entrance to a maze, they would be able to form an internal represenation of a path through the maze by the relatively inefficient strategy of randomly turning at every junction – risking disorientation and a high probability of visiting each blind alley more than once. However, a more efficient strategy for safe passage involves adhering to either the left- or the right-hand wall of the path, thus entering each blind alley only once.

It was argued in Chapter 1 that processing efficiency and representational efficiency are distinct phenomena. To demonstrate this independence empirically presents considerable methodological challenges because standard experimental procedures are not well equipped for teasing apart these different types of efficiency. For example, simple recognition tasks and reproduction tasks are inadequate in this regard because it is likely that the nature of both representations and processing contribute to accuracy on these measures. It is therefore necessary to use different types of measures to illuminate the effects of each brand of efficiency.

### 4.2.2 Indices of processing efficiency

Measures of processing efficiency should examine the 'on-line' processing demands associated with the performance of a rhythm related task. For instance, appropriate indices of processing efficiency may include (a) *auditory inspection time* – for example, the number of times a listener needs to hear a pattern in order to perform some task related to it, and (b) *interference effects*, i.e., the degree to which processing a pattern interferes with a concurrent processing task. Auditory inspection time measures are assumed to be analogous to visual inspection time measures often used to assess processing efficiency in studies of individual differences (e.g., Deary & Caryl, 1990). The suitability of interference effects as an index of processing efficiency derives partly from the fact that the stage of processing (encoding or retrieval) at which the interfering stimulus occurs can be readily manipulated in an experimental setting.

Auditory inspection time measures have been used by Povel and Essens (1985). These researchers recorded the number of times participants listened to repetitively presented patterns before attempting to reproduce them. Although they found that the more complex the pattern was (in terms of fitting their internal clock – see 1.2.3.1), the more times it was listened to, their theoretical orientation led them to interpret this finding in terms of its implications for representational efficiency rather than processing efficiency. Indeed, any conclusions about processing may be difficult to draw due to the nature of their experimental task. It is possible that in their procedure task demands were augmented with relatively complex patterns, not only by increased processing requirements, but also by an increase in motor requirements associated with rehearsing pattern reproductions, because participants were "encouraged to tap along with the sequence during stimulus presentation" (Povel & Essens, 1985, p. 422). Furthermore, it could be argued that Povel and Essens' investigation did not address the perception of truly nonmetrical patterns, as the cyclic nature of the stimuli resulted in an element of periodicity (in the order of 2400 ms to 3200 ms) in even their most irregular patterns. The above issues will be taken into account in the present investigation of auditory inspection time.

The study of interference effects requires the use of multiple task paradigms. Given the relative scarcity of such paradigms in investigations of rhythmic behaviour, the use of interference effect measures is rare. Nevertheless, the results of some research on polyrhythms and other forms of multipart rhythmic behaviour (sees 1.2.3.2.2) can be interpreted in terms of interference effects. For example, Klein and Jones' (1996) findings in studies using multipart patterns comprised of two tone sequences suggest that selective attending to a target sequence is interfered with when the accompanying sequence (which listeners were instructed to ignore) is temporally compatible with the target. However, as noted in earlier chapters, although such research has been informative about musical interactions requiring selective and nonprioritised integrative attending, interactions requiring prioritised integrative attending have not yet been addressed.

### 4.2.3 Indices of representational efficiency

Measures of representational efficiency examine the nature of representations stored in memory (e.g., organisational structures based on hierarchical versus serial relationships), as well as their accuracy. Appropriate indices of representational structure include (a) *memory confusions* and (b) *context effects*. Memory confusion measures assume that errors committed in memory-based tasks reflect the organisation of information in memory. Measures of context effects examine how contextual cues, such as isochronous sequences marking beat- and bar-levels of hypothetical metric hierarchies, affect the interpretation of stored representations. Like memory confusion measures, they assume that behaviour is facilitated when the contextual cues are consistent with the way in which information is organised in memory. Memory confusion and context effect measures both indicate efficient representation to the extent that they provide evidence that the stored information relies on meter's recursiveness.

The effects of contextual cues on rhythm perception have been examined by Povel and Essens (1985) and Palmer and Krumhansl (1990). They employed procedures where isochronous sequences, which were intended to induce various metrical contexts, accompanied the exposure of temporal events. The types of behaviours used to index listeners' representations of these events included goodness-of-fit judgements (Palmer & Krumhansl, 1990; Povel & Essens, 1985) and memory confusions (Palmer & Krumhansl, 1990). The outcomes of these measures indicate that both musicians and nonmusicians can use meter as a framework for representing rhythm patterns. Although this finding is promising, its generality is uncertain. In both investigations, cues to meter were provided during the encoding of temporal events. However, representations of real musical events are frequently formed in the absence of clearly marked metrical contexts. Indeed, it is commonly acknowledged that periodicities acting as cues to meter are often not marked explicitly in musical events (see 1.2.1.2).

## 4.3 Overview of empirical studies to be conducted

The empirical component of the present research examines the relationship between rhythmic complexity, processing efficiency, and representational efficiency in both singlepart and multipart rhythmic contexts. Employing a broad range of contexts where tasks vary markedly in terms of structure and demands is advantageous for several reasons. A practical consideration is that different contexts are suitable for implementing each of the various measures of processing and representational efficiency described above. More theoretical considerations are that using different paradigms should (a) ensure the generality of results and (b) provide converging operations for gaining a more complete conceptualisation of the role of metric frameworks.

### 4.3.1 Singlepart experiments

The experiments addressing rhythmic behaviour in singlepart contexts (which are reported fully in Chapter 5) employ auditory inspection time as an index of processing efficiency, and the effects of contextual cues to meter on the recognition of previously memorised patterns as an index of representational efficiency. As noted earlier, the manner in which these indices have been used in previous research leaves some issues about processing and representational efficiency unresolved. Therefore, precautionary steps are taken here that aim to ensure that the measures of auditory inspection time and context effects are sufficiently rigorous.

The precautions exercised in measuring auditory inspection time are intended specifically to control for confounds relating to motor production and artefactual periodicities. In order to avoid confounding cognitive processing with motor constraints, tasks are perceptual rather than production-based: listeners are required either only to memorise or to make perceptual judgements about certain properties of rhythm patterns. To prevent the artefactual periodicities, such as those that may emerge when nonmetrical patterns are presented cyclically, each pattern is presented discretely.

The way in which the effects of contextual cues on rhythmic behaviour are investigated differs from previous attempts to examine context effects mainly in terms of the stage of processing at which the cues are presented. It was pointed out earlier that existing investigations introduce metrical cues during encoding, and hence do not address the formation of metrical representations for musical events where meter is not clearly marked. One approach to examining the role of meter in representing these events is to focus upon the effects of metrical context on the recognition of patterns that were encoded without explicit cues to meter. Consistent with this approach, the experimental procedure that is employed here involves exposure to a target pattern, followed by recognition memory test phases where, in each phase, target and distracter items are accompanied by context markers that articulate a different meter.

A precedent for this general approach was set by Tulving and Thompson (1973) in work relating to their *encoding specificity principle*. According to the encoding specificity principle, retrieval of information from memory is facilitated by the reinstatement of the context that accompanied encoding. Applying this principle to rhythm suggests that the recognition of patterns that are represented in memory according to particular metrical hierarchies should be facilitated by the provision of appropriate metrical cues during retrieval. Although processing efficiency clearly also contributes to context effects (appropriate contextual cues aid retrieval processes), representational efficiency is paramount because efficient processing (at retrieval) is contingent upon efficient memory organisation.

The singlepart experiments seek not only to demonstrate the effectiveness of the above indices of processing and representational efficiency, but also to address issues relating to the selection of stimulus patterns for use in the multipart experiments. Thus, the singlepart experiments test the psychological validity of the metricality classification scheme upon which multipart stimulus patterns are based.

### 4.3.2 Multipart experiments

Multipart rhythmic textures provide a unique opportunity to measure processing efficiency by examining interference effects. The current multipart experiments exploit this to investigate how rhythmic complexity, musicality, and attending mode affect multipart rhythmic behaviour. General hypotheses about the effects of these factors were outlined in Chapter 3, and specific predictions are made later in Chapter 6. At present, it suffices to note that special focus is given to how rhythmic complexity and musicality influence attentional flexibility in multipart interactions requiring prioritised integrative attending. Basically, the experimental tasks measure, in both musicians and nonmusicians, the degree to which processing target integrant patterns that vary in metricality interferes with the perception of aggregate patterns in which they are embedded. Accuracy of behaviour relating to both target integrant and aggregate patterns is assessed in both recognition memory and production tasks.

Multipart rhythmic complexity is manipulated by varying the metricality of target integrant patterns whilst holding constant the metricality of aggregate patterns. Therefore, experimental stimuli include aggregate patterns from which can be extracted several target integrant patterns that vary in metricality. The complexity of the relationship between target integrant and aggregate patterns is manipulated to produce three conditions, listed here in order of increasing complexity: (a) target integrant and aggregate patterns are both metrical and best fit the same meter; (b) target integrant and aggregate patterns are both metrical, but best fit different meters; (c) nonmetrical target integrant patterns are embedded within metrical aggregate patterns. The principles governing how stimulus parameters are to be controlled in order to establish these relationships are described next, along with other methodological considerations, in the General Method.

## 4.4 General method

The singlepart and multipart experiments reported in this dissertation share some methodological elements. These commonalities relate to experimental design variables, selection criteria for inclusion as a participant, stimuli, and apparatus. Details of these shared elements are discussed here in the general method section. Special attention is given to describing the techniques used to create stimulus patterns. Aspects of the experimental designs and procedures that are unique to each experiment are described later in the relevant chapters.

### 4.4.1 Designs

Experimental design varies considerably from study to study. However, one independent variable that features in each study is metricality. Metricality is treated as a within group factor with three levels: quadruple, triple, and nonmetrical. That is, comparisons are made of performance (indexed by various behavioural measures) under conditions where stimulus patterns best fit a quadruple meter, best fit a triple meter, or are nonmetrical. Some researchers (e.g., Jones, 1985; Yee, Holleran, & Jones, 1994) have recommended that metricality should be treated as a between-subjects factor in order to avoid carryover effects. Despite the advantages of this approach, there is an associated loss of statistical power due to increased error variance. This negative consequence can be avoided by treating metricality as a within-subjects factor and introducing variations in presentation rate between experimental blocks to control for metricality carryover effects. These rate variations are intended to discourage participants from interpreting the stimulus patterns featured in a given experimental block according to metric pulsations established in the immediately preceding block.

Another factor that is included in most of the experiments is musicality. Musicality has two levels: musicians and nonmusicians. Issues relevant to the classification of individuals as musicians or nonmusicians are discussed in the next section.

### 4.4.2 Participants: The issue of musicality

Standards for defining musical skill as a factor in empirical research are virtually nonexistent. Most researchers seem to establish selection criteria in accordance with practical considerations such as the demands of their experimental task or the characteristics of the population to which they have access. Factors typically considered include (a) number of years experience playing an instrument (including voice), (b) number of years of formal instrumental training (e.g., private lessons), (c) number of years of formal music theoretical training, and (d) number of hours spent performing on an instrument during some period (e.g., a month) leading up to the time of experimentation. All but the fourth criterion were considered in the present series of experiments. The fourth criterion was not used because, first, it is difficult to estimate and, second, it can safely be presumed that the members of the population of tertiary music students from which musician participants were drawn practice almost daily. An additional criterion that will be adopted for the multipart experiments in the current study relates to amount of experience as a performer in musical ensembles. The questionnaire used to collect information about participants' musicality and other details is included in Appendix 4.1.

The minimum amount of experience necessary to qualify as a musician in the current investigation is more than six years experience playing an instrument and (for the multipart experiments) current membership as a performer in a musical group or ensemble. Most musicians were second, third, and fourth year Bachelor of Music and Bachelor of Music Education students in the School of Music and Music Education at the University of New South Wales (UNSW). Members of the UNSW symphony orchestra and 'Pipers' concert band (resident at UNSW) were also asked to participate.

Nonmusicians are defined here as individuals who have not played a musical instrument in the past three years and, prior to that period, have not had more than a total of three years experience playing an instrument. Nonmusician participants were drawn from the populations of Psychology 1 students and General Education Psychology students at UNSW.

Only individuals who reported having no hearing difficulties were eligible to participate in the studies.

### 4.4.3 Apparatus

Stimulus parameters were specified in MAX (version 3.0 for singlepart experiments; version 3.5 for multipart experiments), an Apple Macintosh programming environment developed by Opcode. Sounds were generated by Sample Cell, a Macintosh sample player/editor developed by Digidesign, in all experiments except the final multipart experiment, which employed a Roland MT-32 sound module. Stimuli were presented and responses collected by MAX programs running on a Macintosh IIvx computer for all but the final experiment, where a PowerBook 5300cs Macintosh computer was used. Auditory presentations were made over AKG K270 headphones except in the final experiment, which required free field listening and used a Creative SBS-300 speaker. The final multipart experiment used some additional hardware that will be described later when appropriate.

### 4.4.4 Stimuli

#### 4.4.4.1 Rhythm sets

Stimulus patterns for all singlepart and multipart experiments were drawn from 36 specially-constructed rhythm sets. All 36 rhythm sets appear in Appendix 4.2, and an example rhythm set is given in Figure 4.1 and Tracks 26-41. The internal structure of these rhythm sets is described in further detail in section 4.4.4.2. Each rhythm set contains three target integrant patterns. One of the target integrant patterns best fits a *quadruple meter*, another best fits a *triple meter*, and the remaining target integrant pattern is *nonmetrical*. (Duple target integrant patterns were not included primarily due to the high number of elements required to define their structure, which severely limits the number of elements remaining for their related complementary integrant patterns - see following paragraph). There is also a target aggregate pattern that can accommodate each of these integrant patterns in each rhythm set. The target aggregate pattern theoretically best fits a *quadruple meter*.

There are three distracter integrant patterns (d-$x_i$, d-$y_i$, and d-$z_i$) associated with each of the target integrant patterns. All distracter integrant patterns are *nonmetrical*. Also included in the rhythm sets are complementary integrant patterns that, when combined with each target and distracter integrant pattern, result in the target aggregate pattern - as in hocket (see 2.2.1). Finally, there are three distracter aggregate patterns (d-$x_a$, d-$y_a$, and d-$z_a$) in each rhythm set, which, like the target aggregate pattern, best fit a *quadruple meter*. The theoretical classification of these stimulus patterns as quadruple, triple, or nonmetrical is determined by the generative principles used in defining their structure.

## Quadruple integrant patterns

| | |
|---|---|
| Target: | x-----------x---x--------------xx-------x---x-x-x |
| Complement: | ------o-o-o---o------ooooooo-oo-----o--o--------- |
| Distracter-$x_i$: | x-----------x---x------------xx---------x---x-x-x |
| Complement: | ------o-o-o---o------ooooooo---oo---o--o--------- |
| Distracter-$y_i$: | x---------x---x----------------xx-------x---x-x-x |
| Complement: | ------o-o---o---o----ooooooo-oo-----o--o--------- |
| Distracter-$z_i$: | x---------x---x--------------xx---------x---x-x-x |
| Complement: | ------o-o---o---o----ooooooo---oo---o--o--------- |

## Triple integrant patterns

| | |
|---|---|
| Target: | x-------x---x----------xx-----------x-------x-x-x |
| Complement: | ------o---o---o-o----oo--ooo-oooo------oo-------- |
| Distracter-$x_i$: | x-------x---x--------xx-------------x-------x-x-x |
| Complement: | ------o---o---o-o------ooooo-oooo------oo-------- |
| Distracter-$y_i$: | x-----x---x------------xx-----------x-------x-x-x |
| Complement: | --------o---o-o-o----oo--ooo-oooo------oo-------- |
| Distracter-$z_i$: | x-----x---x----------xx-------------x-------x-x-x |
| Complement: | --------o---o-o-o------ooooo-oooo------oo-------- |

## Nonmetrical integrant patterns

| | |
|---|---|
| Target: | x---------x---x-----------xx-----------x----x-x-x |
| Complement: | ------o-o---o---o----ooooo---oooo---o---o-------- |
| Distracter-$x_i$: | x---------x---x---------xx-------------x----x-x-x |
| Complement: | ------o-o---o---o----ooo--oo-oooo---o---o-------- |
| Distracter-$y_i$: | x-------x---x-------------xx-----------x----x-x-x |
| Complement: | ------o---o---o-o----ooooo---oooo---o---o-------- |
| Distracter-$z_i$: | x-------x---x-----------xx-------------x----x-x-x |
| Complement: | ------o---o---o-o----ooo--oo-oooo---o---o-------- |

## Aggregate patterns

| | |
|---|---|
| Target: | v-----v-v-v-v-v-v----vvvvvvv-vvvv---v--vv---v-v-v |
| Distracter-$x_a$: | v-----v-v-v-v-v-v---v--vv---v-v-v----vvvvvvv-vvvv |
| Distracter-$y_a$: | v----vvvvvvv-vvvv-----v-v-v-v-v-v---v--vv---v-v-v |
| Distracter-$z_a$: | v---v--vv---v-v-v----vvvvvvv-vvvv-----v-v-v-v-v-v |

**Figure 4.1:** Example of a rhythm set with target, distracter, and complementary integrant patterns, and target and distracter aggregate patterns.

### 4.4.4.2 Specifying stimulus pattern structure

#### *4.4.4.2.1 Target integrant patterns*

Target integrant patterns consist of several rhythmic figures that are distributed along a grid of 49 time units. Each rhythmic figure contains one or more pattern element/s, where an element is an individual sound event. The rhythmic figures comprising each pattern were selected from a pool of six distinctive rhythmic figures (see Figure 4.2). These rhythmic figures vary not only in terms of the number of elements they contain, but also the number of time units they span. Rhythmic figure [a] consists of a single element and obviously spans only one time unit. Rhythmic figures [b], [c], and [d] each contain two elements, but [b] spans two time unit, [c] spans three time units, and [d] spans four time units. Rhythmic figures [e] and [f] contain three elements and each span five time units.

| | |
|---|---|
| **a** | x |
| **b** | xx |
| **c** | x-x |
| **d** | x---x |
| **e** | x--xx |
| **f** | x-x-x |

**Figure 4.2:** Pool of six rhythmic figures used in target integrant patterns.

Combining these rhythmic figures in various permutations allows distinctive patterns to be created. Only four out of the six rhythmic figures are used in any given pattern. One of these is always rhythmic figure [a], which is featured twice in each pattern. Two of the three two-element rhythmic figures ([b], [c], and [d]), and one of the two three-element rhythmic figures ([e] or [f]), occur once per pattern. Thus, each target integrant pattern consists of a series of five rhythmic figures (two of which are rhythmic figure [a]) and contains a total of nine elements. The first and fourth position in the series are invariably occupied by rhythmic figure [a]. All possible combinations of rhythmic figures are exhausted, within the above constraints, across the 36 rhythm sets such that a unique permutation of rhythmic figures is associated with target integrant patterns in each rhythm set (see Appendix 4.3). The same permutation applies to all target integrant patterns within a rhythm set, regardless of whether they are quadruple, triple, or nonmetrical. The order in which rhythmic figures occur in Appendix 4.3 corresponds to their order of occurrence in the actual target integrant patterns.

The quadruple, triple, and nonmetrical target integrant patterns within each rhythm set are related in the sense that they are composed of identical rhythmic figures. However, the positioning of these rhythmic figures relative to the underlying time unit grid varies for the different types of patterns. This variation is analogous to sliding groups of beads on an abacus in a manner that preserves within-group relationships but alters between-group relationships (see Figure 4.3).

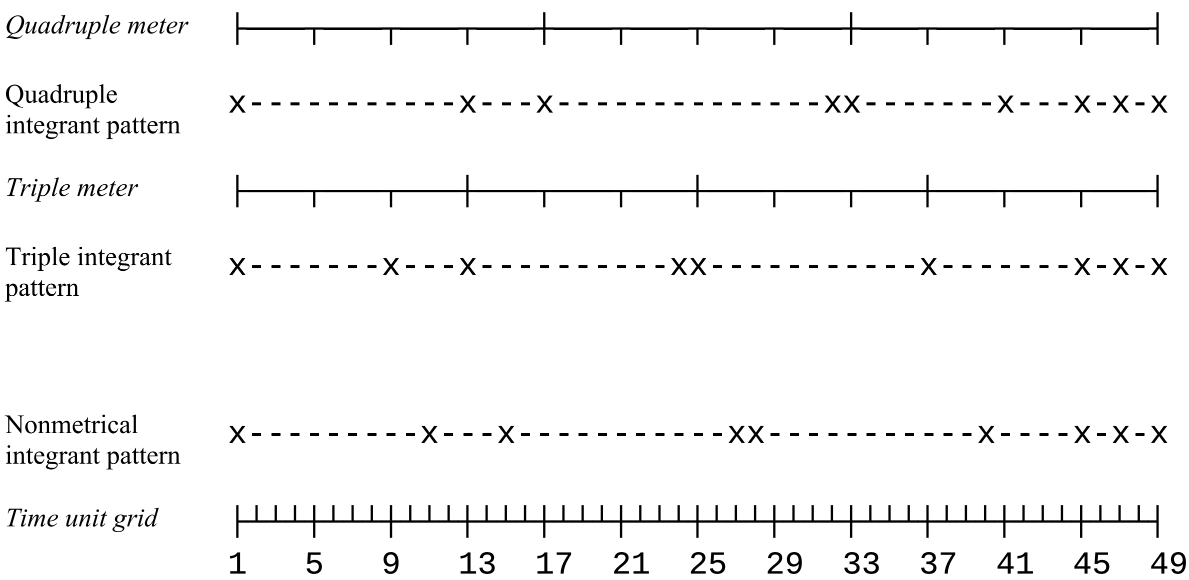


**Figure 4.3:** Quadruple, triple, and nonmetrical integrant patterns from a single rhythm set with quadruple and triple metric frameworks (as well as a time unit grid provided to aid in comparing the structures of metrical and nonmetrical patterns).

The position of rhythmic figures relative to the time unit grid is dictated by three schemes that specify at which time unit to place the final element of each rhythmic figure. These schemes ensure that pattern elements occur periodically in nominal metrical target integrant patterns and aperiodically in nonmetrical target integrant patterns. Specifically, they stipulate that, in order to generate quadruple patterns, the final elements of successive rhythmic figures are placed at time units 1, 17, 33, 41, and 49. To create triple patterns, final elements are placed at time units 1, 13, 25, 37, and 49. In nonmetrical patterns, final elements are placed at time units 1, 15, 28, 40, and 49. The accent rules described in section 1.2.1.3 predict that the time units occupied by the final element of each rhythmic figure will be perceived to be most strongly accented. According to these accent rules, the experience of accent should occur at these locations because a relatively long silent interval follows each final element. It is assumed that these accents serve as cues to group boundaries along the time unit grid. Therefore, each of the three schemes for final element placement (quadruple, triple, and nonmetrical) is suggestive of a different way to divide the time unit grid into groups.

In quadruple target integrant patterns, if the element at time unit 41 is overlooked, the grid of 49 time units is divided into three groups of 16 time units. If it is assumed that groups of four time units correspond to a beat-level period, then the elements occurring at 16 time unit periods can be viewed as quadruple bar-level markers. (The element at time unit 41 simply subdivides the final bar of this quadruple structure into two equal parts). Naturally, this metric interpretation is dependent upon pattern presentation rate, which will be discussed later in section 4.4.4.3.1. Similar principles apply in triple and nonmetrical target integrant patterns. The time unit grid underlying triple integrant patterns is divided into four groups of 12 time units. This grouping structure is consistent with a triple meter where the beat-level period once again spans four time units and the bar-level period spans 12 time units. However, such neat partitioning of the time unit grid does not occur in nonmetrical patterns. In these patterns, the first group consists of 14 time units, the second has 13, the third has 12, and the fourth group contains only 9 time units. This grouping structure clearly does not suggest periodic bar-level divisions, nor does it accommodate an invariant lower level beat period. In all patterns, time unit 49, which is always occupied by an element, is intended to initiate a final group of unspecified duration, and thus imply pattern continuation. This device is employed so that the patterns do not appear to end abruptly when presented.

Figure 4.3 can be used to illustrate how well the various types of target integrant patterns map onto hypothetical quadruple and triple metric frameworks. Note the coincidence between pattern elements and metric pulsations in the metrical patterns, and the lack of such coincidence in the nonmetrical pattern.

#### *4.4.4.2.2 Distracter integrant patterns*

Three distracter integrant patterns (d-$x_i$, d-$y_i$, and d-$z_i$) are associated with each target integrant pattern (see Figure 4.4). These distracter patterns were created by altering the position of one or more rhythmic figure/s relative to the time unit grid. Specifically, the alteration occurred in the position of the second and/or the third rhythmic figure in the series of five figures that comprised each pattern. (The final rhythmic figure was not altered in order to preserve overall pattern duration and to guard against recency effects). These variations always involved moving the relevant rhythmic figure/s backwards by two time units. Therefore, when distracter integrant patterns are presented, these figures occur earlier in time than they do in target integrant patterns. In distracter-$x_i$ integrant patterns, the third rhythmic figure in the series was shifted back two time units relative to its placement in the target pattern. In distracter-$y_i$ integrant patterns, the third rhythmic figure was shifted. Finally, in distracter-$z_i$ patterns, the second and third rhythmic figures were both advanced by two time units. Note that these alterations render all three types of distracter integrant pattern nonmetrical (see Figure 4.4). The final elements of rhythmic figures that coincide with metric bar-level pulses in metrical target patterns anticipate these pulses by two time units in distracter patterns.

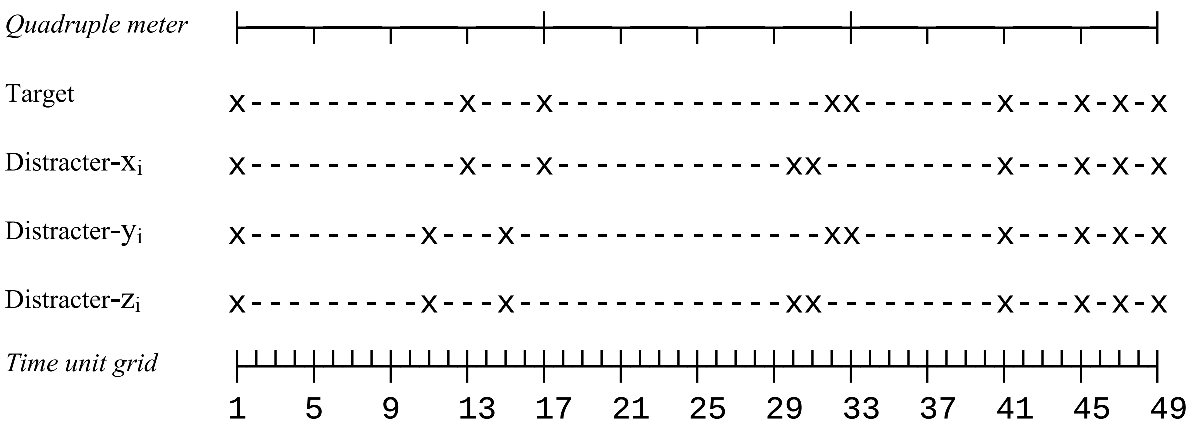


**Figure 4.4:** Quadruple target and distracter-$x_i$, -$y_i$ , and –$z_i$ integrant patterns.

#### *4.4.4.2.3 Target and distracter aggregate patterns*

The target aggregate pattern associated with each rhythm set was generated by combining (as if by superimposition) all target and distracter integrant patterns from its rhythm set. In other words, the structure of target aggregate patterns is, as their name implies, the same as the structure that would emerge if the quadruple, triple, and nonmetrical target integrant patterns within a particular rhythm set, and their related distracter integrant patterns, were all presented simultaneously. The number of elements in each target aggregate pattern varies according to rhythm set (although overall length is a constant 49 time units). Number of elements ranges from 21 to 28, with an average of 24.67 elements.

The method of collapsing across all target and distracter integrant patterns regardless of metricality produces target aggregate patterns whose structure is compatible with both quadruple and triple metric frameworks (see Figure 4.5). However, although target integrant patterns are metrically ambiguous, they are more readily accommodated by quadruple, than by triple metric frameworks. This claim, once again, relates to the way in which the time unit grid is segmented by the accents implied by the relative placement of pattern elements. In each pattern there are, on average, more empty time units following elements that coincide with hypothetical quadruple bar-level pulses (which occur every 16 time units), than following elements coinciding with triple bar-level pulses (occurring every 12 time units) (see Appendix 4.4). Therefore, all other things being equal, elements marking quadruple bar-level pulses should be perceptually more salient than those marking triple bar-level pulses. This pattern of accentuation suggests a quadruple grouping structure.

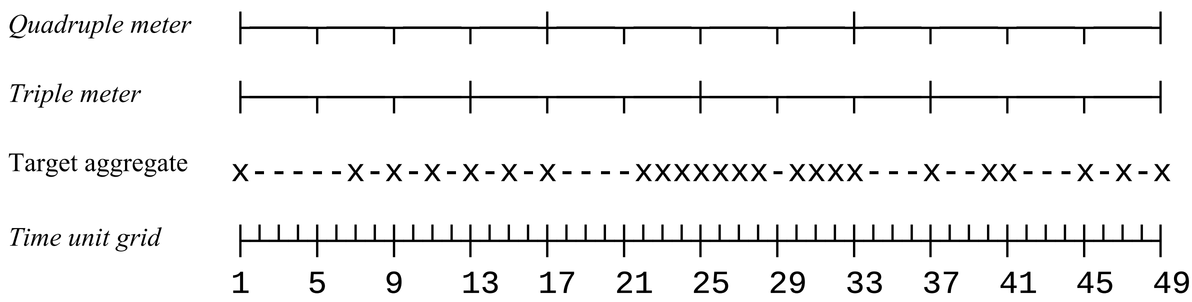


**Figure 4.5:** Metrically ambiguous target aggregate pattern that maps onto both quadruple and triple frameworks, but best fits the quadruple framework.

Three distracter aggregate patterns (d-$x_a$, d-$y_a$, and d-$z_a$) are associated with each target aggregate pattern. The first step in creating these distracter patterns was to partition the target aggregate patterns into three groups of 16 time units (in accordance with their quadruple structure) (see Figure 4.6). Time units 1 to 16 are labelled as group A, time units 17 to 32 as group B, and time units 33 to 48 as group C (recall that time unit 49 is included only to imply pattern continuation). After partitioning, the order in which these three groups occurred was varied for each distracter pattern. Specifically, the original order in which groups appeared in the target aggregate pattern (ABC) become ACB in distracter-$x_a$, BAC in distracter-$y_a$, and CBA in distracter-$z_a$. These orders were chosen because they allow each group to appear at each ordinal position in the three group series without replicating the adjacent pairings (AB, BC) featured in original order. The process of generating distracter aggregate patterns deliberately preserves the quadruple structure implied by target aggregate patterns.

```
                 |---------A---------|---------B---------|---------C---------|
Target           v-----v-v-v-v-v-v----vvvvvvv-vvvv---v--vv---v-v-v

                 |---------A---------|---------C---------|---------B---------|
Distracter-xa    v-----v-v-v-v-v-v---v--vv---v-v-v----vvvvvvv-vvvv

                 |---------B---------|---------A---------|---------C---------|
Distracter-ya    v----vvvvvvv-vvvv-----v-v-v-v-v-v---v--vv---v-v-v

                 |---------C---------|---------B---------|---------A---------|
Distracter-za    v---v--vv---v-v-v----vvvvvvv-vvvv-----v-v-v-v-v-v

Time unit grid   1   5   9   13  17  21  25  29  33  37  41  45  49
```

**Figure 4.6:** Target and distracter-$x_a$, -$y_a$, and –$z_a$ aggregate patterns.

### *4.4.4.2.4 Complementary integrant patterns*

Each target and distracter integrant pattern is associated with a complementary integrant pattern (see Figure 4.1). These complementary integrant patterns simply supplement their related target and distracter integrant patterns by providing the necessary elements to produce the target aggregate pattern. Therefore, when complementary integrant patterns and their related integrant patterns are presented concurrently, they mesh to form the target aggregate pattern. The number of elements in complementary patterns is variable, and can be obtained by subtracting the number of elements in the related target or distracter integrant pattern (which is always 9) from the number of elements in the relevant target aggregate pattern. Complementary integrant patterns are considered to be mere ‘gap-fillers’, and hence no attempt has been made to evaluate their structure in terms of metricality.

#### 4.4.4.3 Realtime presentation issues

##### *4.4.4.3.1 Time unit duration*

The above classification of stimulus patterns as quadruple, triple, and nonmetrical assumes that, in metrical stimulus patterns, beat-level pulses correspond to groups of four time units. Whether participants actually experience beat-level pulses that span four time units clearly depends upon the rate, or tempo (in the case of metrical patterns), at which patterns are presented. In the present stimuli, pattern presentation rate is determined by the duration of time units: lengthening time unit duration makes the rate slower, whereas shortening time unit duration makes rate faster. In section 1.2.1.2, it was noted that the experience of pulse is limited to certain tempos. The region of greatest pulse salience was said to be bounded by periodicities of 400 ms and 900 ms, with the most salient pulsations within this range having a 600 ms period. In order to establish tempos (based on groups of four time units) that reflect these constraints, the duration of individual time units must lie between 100 ms and 225 ms. The most salient pulse period corresponds to a time unit duration of 150 ms.

As mentioned earlier, metricality carryover effects can be controlled by varying presentation rate between experimental trials or blocks (depending on the procedure). In experiments where the task is such that metricality carryover effects are unlikely to be problematic (or when varying presentation rate would be impractical), time unit duration will be set at 150 ms. Otherwise, when variations in presentation rate are desirable, time unit duration is selected from three possible values: fast, medium, and slow. In the first singlepart experiment, fast time unit duration is 135 ms, medium time unit duration is 150 ms, and slow time unit duration is 174 ms. These values were chosen on the basis of a rate discrimination pilot study employing musically skilled participants. In subsequent experiments, these values are changed to 129 ms (fast), 150 ms (medium), or 179 ms (slow). These values are based on a more extensive rate discrimination experiment described in Appendix 4.5. This experiment examines the effects of various factors, including metricality, musicality, direction of rate change (increasing, decreasing), and rate region (slow, fast), upon ability to detect changes in presentation rate. The time unit duration values given above are associated with presentation rates that are discriminable, on average, at all levels across these factors. Overall, the experimental results indicate that, assuming 150 ms corresponds to a preferred, or central, presentation rate, time unit duration must decrease or increase by at least 16% (yielding durations of 129 ms and 179 ms, respectively) in order for the change to be noticed. Both liminal values lead to hypothetical beat periods that lie within the region of greatest pulse salience: combining four time units results in a beat period of 516 ms when time unit duration is 129 ms, and 716 ms when individual time unit duration is 179 ms.

#### *4.4.4.3.2 Sounds used as pattern elements*

Various percussive sounds were used to articulate the stimulus patterns. These sounds were selected from the libraries of percussion instrument samples available in Sample Cell and the Roland sound module. Several criteria were used in the selection process. Primary considerations were that sounds each (a) have a single clearly marked onset, or attack, and (b) decay rapidly following onset so that the onset of the next sound is clearly audible when the sounds are presented sequentially at the fastest rate (where time unit duration is 129 ms). In addition, only percussion sounds that are likely to be familiar to Western listeners were considered as candidates. The pool of sounds compiled in this way includes samples of conga, bongo, and snare drums, as well as a closed hi-hat cymbal, woodblock, and cowbell. This variety of percussion sounds allows target integrant patterns to be associated with different instruments to complementary integrant patterns and metrical context markers (when required) in multipart stimuli, thus making these separate parts readily discriminable.

### 4.4.4.4 Validating the metricality classification scheme

The metricality classification scheme described earlier is purely theoretical. The predictions it embodies about the metricality of stimulus patterns are based solely upon the placement of pattern elements relative to a latent time unit grid. Behavioural experiments are necessary to determine whether these predictions hold when the patterns are auditorily realised. The need to establish the psychological reality of the metricality classification scheme arises through issues related to the distinction between the objective physical characteristics of patterns and the subjective internal representations that result from attenders' perceptual and cognitive processing (see 1.2.1.1.2). However, as a precursor to behavioural measures, statistical techniques such as autocorrelation may provide useful indices of metricality.

An autocorrelation analysis was run to provide an objective means of detecting periodicities in the stimulus patterns. This analysis is described in detail in Appendix 4.6. Briefly, this form of analysis involves examining the strength of correlation between versions of a pattern where the initial element coincides with the first time unit (i.e., the original version of the pattern), and where it is placed at lag intervals corresponding to successive points moving forward along the time unit grid. In other words, the pattern is phase shifted relative to itself, and the relationship compared at each shift. This statistical technique is useful to the extent that it has the potential to reveal structural regularities that are not readily detected by conventional forms of music analysis. Thus, autocorrelation allows the validity of the generative principles used in creating stimulus patterns to be checked. It is especially useful for validating the classification of nonmetrical patterns, as the generative principles employed provide more explicit guidelines for introducing periodicities than for avoiding them.

Basically, the results of the autocorrelation analysis reported in Appendix 4.6 support the theoretical classification of stimulus patterns. In quadruple and triple target integrant patterns, the periodicities uncovered were consistent with their theoretical metricality. Nonmetrical and distracter integrant patterns generally lacked periodic components, which is likewise consistent with their theoretical classification (although periodicities suggestive of a triple meter were revealed in a minority of theoretically nonmetrical patterns). The profile of aggregate patterns is slightly more complex. Various periodicities emerged, but they did not suggest commitment to any particular metric framework. This is consistent with the classification of aggregate patterns as metrically ambiguous.

The findings of the autocorrelation analysis should be interpreted with caution. Such objective statistical techniques fail to take into account subjective factors such as the accentuation of patterns elements and the effects of presentation rate. Hence, the need arises to assess metricality through behavioural experiments. The singlepart experiments that are reported in Chapter 5 test the psychological reality of the theoretical metricality classification scheme, in addition to investigating other issues in the processing and representation of rhythm.

# CHAPTER 5

## METER IN THE PROCESSING AND REPRESENTATION OF SINGLEPART PATTERNS

Two experiments examining the role of metric frameworks in the processing and representation of singlepart musical rhythm patterns are reported in this chapter. Both test the hypothesis that metrical patterns are processed and represented more efficiently than nonmetrical patterns. The first experiment relies upon declarative knowledge of meter, and uses musical experts as participants. The second does not require declarative knowledge of meter, and uses both musicians and nonmusicians as participants.

# 5.1 Singlepart aims

In this chapter, two singlepart experiments are presented. Each investigates the effects of rhythmic complexity, or metricality, upon the efficiency with which singlepart patterns are both processed and represented. Independent measures of processing and representational efficiency are employed in each study, although the emphasis is on processing in Singlepart Experiment 1, and on representation in Singlepart Experiment 2. It is generally expected that processing and representational efficiency will be enhanced when attenders are given the opportunity to generate appropriate metric frameworks with which to guide pattern interpretation. These studies will also serve as foundations for the two multipart experiments in Chapter 6.

In contrast to the later multipart experiments, the tasks in the two singlepart experiments do not require use of advanced attentional strategies such as prioritised integrative attending. The relatively uncomplicated rhythmic textures and attentional demands that characterise the current experiments provide a suitable context in which to validate empirically the theoretical metricality classification scheme described in section 4.4.4. The metricality scheme is assumed to be valid to the extent that the results of the singlepart experiments indicate different degrees of processing and representational efficiency for theoretically metrical and nonmetrical patterns.

# 5.2 Singlepart Experiment 1: Expert metricality judgements

## 5.2.1 Introduction

Singlepart Experiment 1 examines the relationship between theoretical metricality, perceived metricality, and auditory inspection time. Theoretical metricality is determined by the objective structural features that define rhythm patterns, and is reflected by the classification of patterns in each of the rhythm sets described in section 4.4.4. This particular classification scheme is based mainly on considerations such as whether pattern elements occur periodically, and, if more than one level of periodicity is suggested, the ratio relating periods at different levels. Other factors relevant to the scheme include the relative duration of silent intervals following pattern elements and the absolute rate at which patterns are presented. According to these considerations, patterns from the rhythm sets were categorised as either theoretically best-fitting a quadruple meter, best-fitting a triple meter, or nonmetrical (see 4.4.4 for further details).

Theoretical metricality embodies explicit predictions about perceived metricality. Perceived metricality refers to an attender's subjective interpretation of a pattern unfolding in real time. Singlepart Experiment 1 tests perceived metricality by requiring expert listeners (musicians who have explicit, or declarative, knowledge of the concept of musical meter) to judge the metricality of patterns from different theoretical metricality categories. The experimental task involves rating each individual target pattern from the 36 rhythm sets described in section 4.4.4 on *two* separate scales, one indicating fit to a quadruple meter and the other indicating fit to a triple meter. The use of a greater variety of frameworks against which to make ratings is impractical because of the large number of patterns contained in the rhythm sets.

Alternatives to the rating approach include asking listeners, in an open-ended fashion, to identify meter of best fit for each pattern, or to tap along with a felt beat. The identification approach was not adopted here mainly because for each pattern it yields only a single response that is difficult to quantify (as opposed to the two ratings per pattern in the rating approach). The qualitative aspects of these responses make the approach unsuitable for comparing the relative degree to which different patterns fit into a particular metricality category. Furthermore, the identification approach is not necessarily informative about how well a particular pattern fits into different metricality categories. Therefore, its usefulness for assessing metrical ambiguity is limited. These limits are imposed not only by the qualitative nature of the identification approach, but also, more fundamentally, because information about the relative suitability of competing frameworks is lost in methods that require only a single interpretation to be reported. (It would be unfeasible under current circumstances to ask listeners to comment on how they arrive at such final interpretations, identifying metric hypotheses that were entertained along the way, due to the large number of patterns). The other alternative to the rating approach – beat tapping – was rejected because it necessitates that patterns are presented cyclically. Such recycling would be inappropriate in the current investigation because it introduces artefactual periodicities (albeit rather large) into theoretically nonmetrical patterns.

Ratings produced in the metricality judgement task used in the present experiment are expected generally to reflect theoretical metricality. Therefore, theoretically quadruple patterns should receive higher ratings on the quadruple than the triple scale, theoretically triple patterns should receive higher ratings on the triple than the quadruple scale, and theoretically nonmetrical patterns should receive low ratings on both scales. This pattern of results would suggest that there is close correspondence between perceived and theoretical metricality. Such findings would thus provide evidence for the psychological reality of the theoretical metricality classifications. Although perceived metricality, as measured by metricality judgements, is not a direct index of representational efficiency, it reflects the *potential* for patterns to be represented efficiently according to metric frameworks.

In the experimental task, experts are permitted to listen to each pattern as many times as they desire when judging its metricality. The number of times experts choose to hear each pattern serves as a measure of auditory inspection time, and, as such, is assumed to be an index of processing efficiency. Specifically, it is assumed that the fewer number of hearings the greater the processing efficiency. Therefore, in accordance with the hypothesis that metrical patterns are processed more efficiently than nonmetrical patterns, it is expected that nonmetrical patterns will need to be heard more times than metrical patterns whilst making metricality judgements. Furthermore, processing efficiency is expected to vary according to how well theoretically quadruple and triple patterns are perceived to fit their respective metric frameworks. Therefore, several distinct types of relationships are expected to emerge between number of hearings, metricality judgements, and theoretical metricality.

In the case of theoretically quadruple patterns, increasing correspondence between theoretical and perceived metricality should be associated with decreasing number of hearings when ratings are made according to the quadruple scale, and increasing number of hearings when rating on the triple scale. On the other hand, in the case of theoretically triple patterns, as correspondence between theoretical and perceived metricality increases, number of hearings should decrease when using the triple scale, but increase when using the quadruple scale. Finally, there should be no clear relationship between number of hearings and metricality judgements for theoretically nonmetrical patterns.

## 5.2.2 Method

### 5.2.2.1 Participants

Four expert musicians participated in Singlepart Experiment 1. All held at least an undergraduate degree in music, were experienced composers, had taught in university music courses, and, most importantly, possessed declarative knowledge and a detailed understanding of musical meter. All participants were male, and their average age was 29 years.

#### 5.2.2.2 Design

A (4 x 2) repeated measures design was employed, where the within group variables are *theoretical pattern type* (quadruple integrant; triple integrant; nonmetrical integrant; aggregate – see 4.4.4) and *interpretive framework* (quadruple; triple). The factorial combination of these variables results in eight experimental conditions. These eight conditions were presented across two experimental sessions. One session contained the four conditions where theoretically quadruple, triple, and nonmetrical integrant, and (quadruple) aggregate, patterns were interpreted within a quadruple framework. The other session featured the remaining conditions where quadruple, triple, and nonmetrical integrant, and aggregate, patterns were interpreted within a triple framework. Session order was counterbalanced.

#### 5.2.2.3 Stimuli and apparatus

From each of the 36 rhythm sets described in section 4.4.4, the three target integrant patterns (quadruple, triple, and nonmetrical) plus the target aggregate pattern, were included here. These 144 patterns were arranged in 12 pools, each containing 12 patterns.[12] All target integrant and aggregate patterns from the 36 rhythm sets are represented across the 12 pools such that, within each pool, there are three quadruple integrant patterns, three triple integrant patterns, three nonmetrical integrant patterns, and three quadruple aggregate patterns (see Appendix 5.1). All patterns were articulated by a woodblock sound with a MIDI velocity value of 96 (possible values range from 1 to 120). Participants were given the opportunity to adjust the loudness level if it was not comfortable, but none of them chose to do so.

Apparatus consisted of AKG headphones and MAX software running on a Macintosh computer, as described in section 4.4.3.

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[12] Note that as well as target integrant and aggregate patterns the rhythm sets also contain distracter patterns. It is necessary to assess only target integrant pattern metricality because it is these that will be a variable in future experiments. Distracter aggregate patterns are not included because they merely involve changing the order in which metric groups occur in target aggregate patterns.

#### 5.2.2.4 Procedure

Participants were tested individually at a computer in a small sound attenuated room. Testing took place over two experimental sessions – one for each interpretive framework (quadruple or triple) – separated by approximately one week. All 12 pools of stimulus patterns were presented to the participant in each of the two sessions. In each session there were 12 blocks, one for each stimulus pool. Blocks were run in four counterbalanced orders (see Appendix 5.2). Each block consisted of 12 trials one for each of the 12 stimulus pool items. Therefore, within each block, three trials featured quadruple integrant patterns, three featured triple integrant patterns, three featured nonmetrical integrant patterns, and three featured quadruple aggregate patterns. Trial order was randomised within blocks. Participants were allowed to rest between blocks as they felt necessary. Presentation rate varied between blocks in accordance with guidelines provided in section 4.4.4.3.1. Ratings indicating fit to a quadruple meter and ratings indicating fit to a triple meter were made in the two separate experimental sessions. Two participants completed the session involving quadruple ratings first, whereas the other two participants started with the session involving triple ratings.

Participants were given both written and oral task instructions about the task prior to the commencement of each experimental session (see Appendix 5.3). When the participant and experimenter agreed that the procedure was fully understood, four practice trials were presented. Each practice trial featured one item: either a quadruple integrant, a triple integrant, a nonmetrical integrant, or a quadruple aggregate pattern. No feedback was provided. When the participant indicated that they were ready, the experimental session commenced.

Depressing the ‘spacebar’ on the computer keyboard initiated a presentation of the stimulus pattern associated with a particular trial. The participant was required to rate on a four point scale (ranging from 1, “does not fit”, to 4, “very good fit” – see Appendix 5.4) how well the pattern contained in the trial fit either a quadruple or a triple meter. The participant was permitted to listen to each pattern as many times as required to make their ratings – all they needed to do was to depress the spacebar again after pattern completion. The number of times participants chose to hear each pattern was recorded by the computer. Additionally, for each trial, the participant was asked to indicate which beat of the current interpretive framework they felt coincided with the first element of the stimulus pattern. The options provided were beats 1, 2, 3, or 4 for the quadruple framework, and beats 1, 2, or 3 for the triple framework. The participant indicated their response by clicking with the computer mouse within a check box on the computer screen. The purpose of this task was to determine whether each pattern's perceived phase (i.e., starting point relative to metric beat- and bar-level pulses) is consistent with the assumption that all metrical patterns from the rhythm sets begin on the first beat of their best-fitting metric framework.

### 5.2.2.5 Results

#### *5.2.2.5.1 Perceived metricality*

Average ratings of the degree to which quadruple integrant, triple integrant, nonmetrical integrant, and aggregate patterns from each the 36 rhythm sets fit both quadruple and triple meters are shown in Figure 5.1. Each pattern is represented by a single data point with (x,y) coordinates, in which the abscissa indicates the average rating relative to the quadruple scale and the ordinate indicates the average triple scale rating.

The area bounded by the (horizontal) quadruple rating axis and the (vertical) triple rating axis of the graph in Figure 5.1 can be divided into four regions, each roughly corresponding to a different category in perceived metricality space. Each section is bounded by a line drawn perpendicularly from the rating 2 point on the abscissa and the ordinate. Thus, data points lying in the lower right region, where quadruple rating $\geq 2$ and triple rating $\leq 2$, indicate that the relevant patterns were perceived to be exclusively quadruple (a rating of 1 indicates "does not fit"). Points falling in the upper left region, where quadruple rating $\leq 2$ but triple rating $\geq 2$, indicate that patterns were perceived to be exclusively triple. Patterns whose coordinates fall within the lower left region, where quadruple rating and triple rating $\leq 2$, were perceived to be nonmetrical. Patterns whose coordinates occupy the upper right region, where quadruple rating and triple rating $\geq 2$, were perceived to be metrically ambiguous, fitting both quadruple and triple meters.

As can be seen in Figure 5.1, the majority of ratings for quadruple integrant patterns are confined to the quadruple region in perceived metricality space, although some cross over into the lower right part of the ambiguous region. This suggests that even though all quadruple integrant patterns were perceived to best fit a quadruple meter, participants were able to interpret some of these patterns according to a triple meter. Similarly for triple integrant patterns, most ratings are located in triple perceived metricality space, although there is ambiguity associated with some triple integrant pattern ratings. However, this ambiguity appears to be weaker than in the quadruple counterpart in terms of both frequency (fewer data points lie within ambiguous metricality space) and magnitiude (data points do not intrude as deeply into ambiguous metricality space).

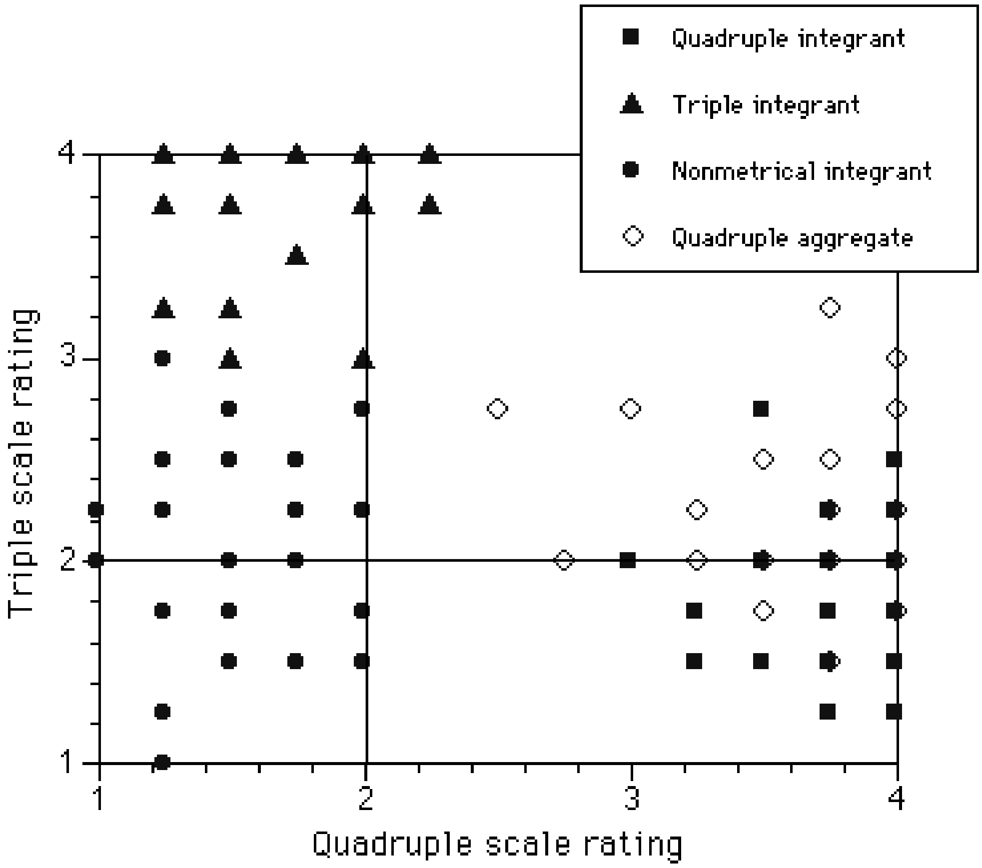


**Figure 5.1:** Metricality ratings for quadruple integrant, triple integrant, nonmetrical integrant, and aggregate patterns from each the 36 rhythm sets averaged over participants. Each pattern is represented by a single data point in which the abscissa indicates the average rating relative to the quadruple scale and the ordinate indicates the average triple scale rating. There are fewer than 36 data points in each of the four pattern categories because of overlap due to patterns from different rhythm sets receiving the same average metricality rating in some cases. More detailed information about the actual values of ratings for patterns from specific rhythm sets is provided in Appendix 5.5.

Metricality judgements of patterns from the nonmetrical category are not entirely consistent with theoretical predictions. Approximately half of the nonmetrical integrant pattern ratings fall within the nonmetrical region in perceived metricality space. The remaining nonmetrical patterns occupy the lower portion of the triple region in metricality space, suggesting that participants had moderate success at interpreting these patterns according to a triple framework.

Finally, ratings for aggregate patterns, which are in theory ambiguous but fit a quadruple meter better than a triple meter, span both quadruple and ambiguous regions in perceived metricality space. This suggests that some aggregate patterns were perceived to fit solely within a quadruple framework, whereas others were perceived to fit both quadruple and triple frameworks.

It was generally the case that when patterns were judged to fit an interpretive framework, they were perceived to begin on the first beat of the bar within that framework. That is, perceived phase of metrical patterns is aligned with their corresponding framework such that the first pattern element coincides with a bar-level metric pulsation. This tendency was strongest when theoretically metrical patterns were rated according to their meter of best fit. In fact, exceptions were almost nonexistent under these circumstances. Figure 5.2 provides some indication of how infrequently patterns were judged to begin at a metric location other than the first beat.[13]

In summary, metricality judgements reveal that, despite minor inconsistencies, there is general correspondence between theoretical and perceived metricality. Even though several quadruple and triple integrant patterns were perceived as metrically ambiguous, all quadruple integrant patterns were judged to best fit a quadruple meter and all triple integrant patterns were judged to best fit a triple meter. That is, although the ambiguous quadruple and triple patterns, by definition, could be interpreted either way, participants favoured the interpretation consistent with theoretical metricality.

Furthermore, although a relatively high proportion of aggregate patterns were perceived as ambiguous, they were still judged to best fit a quadruple meter. The inconsistencies evident in nonmetrical patterns were more remarkable than those in metrical patterns. Approximately half of the nonmetrical patterns were interpretable within a triple framework, although they were judged to fit such a framework relatively poorly. The finding that some theoretically quadruple, triple, and nonmetrical patterns cross over into regions of perceived metricality space that neighbour their respective predicted regions suggests that the 36 rhythm sets vary in the degree to which their constituents exemplify the theoretical metricality categories.

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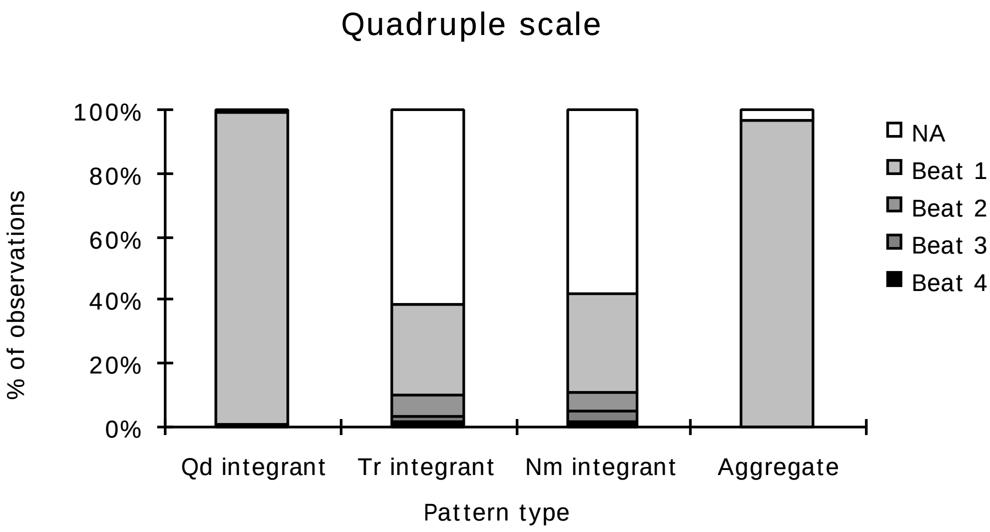
[13] Caution should be taken not to attribute too much importance to these results pertaining to phase, as their reliability may be questionable due to the fact that phase was not manipulated systematically in the experimental procedure.



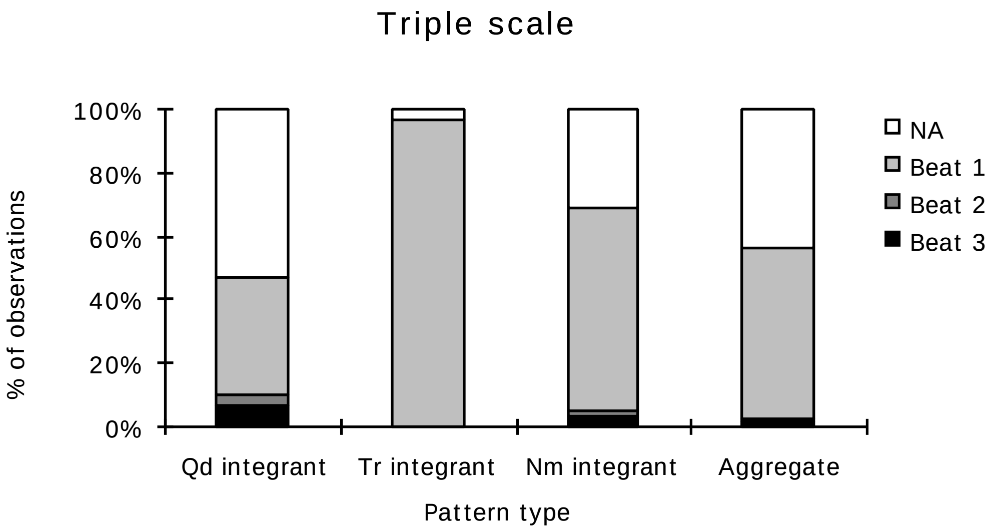




**Figure 5.2:** Perceived phase is shown in the following figures as the percentage of patterns in each theoretical metricality category (pattern type) that were perceived to begin at each of several possible metric beat locations. The top panel shows perceived phase when using a quadruple interpretive framework, and the bottom panel shows perceived phase when using a triple interpretive framework. 'NA' stands for 'not applicable', and represents cases where the participant gave a 'does not fit' rating and therefore was not asked to report perceived phase.

#### *5.2.2.5.2 Auditory inspection time*

To examine the relationship between auditory inspection time and perceived metricality, correlation coefficients were calculated between number of times participants required patterns to were heard whilst making metricality ratings, and the values of the ratings themselves. As shown in Table 5.1, separate Pearson *r* coefficients were computed for each of the eight theoretical pattern type x interpretive framework experimental conditions. Raw scores for number of hearings and metricality ratings were used rather than averages (i.e., scores were not averaged across participants). Therefore, each coefficient in Table 5.1 represents the strength of correlation between number of hearings and metricality ratings across 144 pairs of observations (4 participants x 36 patterns) within a single experimental condition.

**Table 5.1:** Correlation between *perceived metricality* (ratings on quadruple and triple scales) and *auditory inspection time* (number of hearings required to make quadruple and triple ratings).

| | Interpretive framework | | | |
|---|---|---|---|---|
| **Theoretical pattern type** | *Quadruple* | | *Triple* | |
| **Quadruple integrant** | -0.219 | * | 0.542 | **** |
| **Triple integrant** | 0.416 | **** | -0.293 | *** |
| **Nonmetrical integrant** | 0.213 | * | -0.056 | |
| **Quadruple aggregate** | -0.314 | *** | 0.074 | |

*Note:* * p<.05; ** p<.02; *** p<.01; **** p<.001

Significant correlations were observed between number of hearings and metricality ratings for all theoretical pattern types. For quadruple integrant patterns, there was weak but significant negative correlation between number of hearings and metricality ratings ($r$ = -0.22) when ratings were made according to the quadruple scale. In other words, the greater the degree to which theoretically quadruple integrant patterns were judged to fit a quadruple meter, the fewer the number of hearings required to make the judgements. Conversely, when theoretically quadruple integrant patterns were judged against the triple scale, the correlation between number of hearings and metricality ratings was moderate and positive ($r$ = 0.53). That is, number of hearings increased with greater conformity of theoretically quadruple patterns to a triple meter. The correlations observed with theoretically triple integrant patterns complement those obtained with their quadruple counterparts. When triple patterns were judged against the triple scale, number of hearings and metricality ratings were negatively correlated ($r$ = -0.29), whereas when triple patterns were judged against the quadruple scale, positive correlations were obtained ($r$ = 0.42).

The above results for quadruple and triple integrant patterns indicate that, generally, when the interpretive framework was consistent with theoretical metricality, number of hearings and metricality ratings were negatively correlated. On the other hand, the correlation between number of hearings and metricality ratings was positive when the interpretive framework was inconsistent with theoretical metricality.

The complementarity of the correlations for consistent framework and theoretical metricality, and inconsistent framework and theoretical metricality, suggests that the direction of correlation between auditory inspection time and metricality judgements varies as a function of whether the current interpretive framework is theoretically the best-fitting metric framework. The effects of interpretive framework are less clear-cut in theoretically nonmetrical integrant patterns (as predicted) and aggregate patterns.

In the case of nonmetrical integrant patterns and aggregate patterns, number of hearings and metricality ratings were correlated only when a quadruple interpretive framework was used, although the direction of correlation was different for each theoretical pattern type. For nonmetrical integrant patterns, like triple integrant patterns, there was a weak but significant positive correlation between number of hearings and metricality ratings when fit to a quadruple meter was judged ($r = 0.21$). However, number of hearings and metricality ratings were uncorrelated when fit to a triple meter was judged ($r = -0.06$). For aggregate patterns, like quadruple integrant patterns, there was weak negative correlation between number of hearings and metricality ratings when patterns were judged against the quadruple scale ($r = -0.31$). However, unlike quadruple integrant patterns, number of hearings and metricality ratings were uncorrelated when aggregate patterns were judged against the triple scale ($r = 0.07$).

To examine the relationship between auditory inspection time and perceived metricality further, the 36 rhythm sets were ordered from 'best' to 'poorest' according to the degree to which metricality ratings indicated that they contain good exemplars of quadruple, triple, and nonmetrical integrant patterns. Aggregate patterns were not considered in this ordering procedure because they not only consist of more pattern elements than integrant patterns, but the number of pattern elements they contain also varies between rhythm sets (see 4.4.4.2.3). Therefore, it is questionable whether aggregate patterns can be compared directly to integrant patterns, or even to each other, in terms of complexity.

The first step in deriving this order was to calculate a 'metricality score' for each integrant pattern. Metricality scores were calculated by subtracting the average rating each integrant pattern received on the triple scale from their average quadruple scale rating. The resulting scores potentially ranged from –3 to +3. Positive scores indicate that a pattern best fits a quadruple meter whereas negative scores indicate that the pattern best fits a triple meter. In both cases, the greater the absolute value of the score the better the fit. Scores that lie within the range of –1 to +1 will be taken to indicate that a pattern is either nonmetrical or highly ambiguous metrically (metricality scores themselves are not sensitive to the distinction between nonmetrical and ambiguous patterns). Metricality scores for all patterns from the 36 rhythm sets are plotted in Appendix 5.6.

Once metricality scores had been calculated, rhythm sets were ordered according to a procedure that took into account the size of the difference between the absolute value of metricality scores for the theoretically metrical (quadruple and triple) and nonmetrical integrant patterns in each rhythm set, and on the basis of rankings divided into three groupings, the 11 best, the 11 poorest, and 14 mediocre (see Appendix 5.7).[14] Differences between metricality scores for metrical and nonmetrical patterns are maximal when these patterns receive extremely high and low scores, respectively. Thus, increases in the difference between metricality scores for metrical and nonmetrical patterns indicate increasing correspondence between theoretical and perceived metricality. Therefore, to the extent that large differences in metricality scores are observed within a particular rhythm set, it can be assumed that this rhythm set contains good exemplars of metrical and nonmetrical patterns.

To test the validity of this rudimentary technique for ordering rhythm sets, an alternative ordering method was employed some time after the results of Singlepart Experiment 1 had been analysed. This new technique involved plotting the (x,y) coordinates in metricality space (as in Figure 5.1) for the three integrant patterns (quadruple, triple, and nonmetrical) from each of the 36 rhythm sets separately. Then the area in metricality space bounded by the three points related to each rhythm set was calculated. Finally, rhythm sets were ordered from the one that occupied the largest area in metricality space to the one with the smallest area (see Appendix 5.8). It is assumed that rhythm set quality improves with increasing area because a larger area represents more extreme ratings. In support of the validity of the rhythm set order based on metricality scores (described earlier), there is a high correlation between metricality score order and the order based on area in metricality space ($r$ = 0.79, $p<.001$).

[14] Unequal groupings were necessary to keep together rhythm sets that obtained the same metricality difference score.

Using the metricality score order, a (3 x 3) categorisation of patterns was made based on metricality (triple; quadruple; nonmetrical) and the quality of rhythm sets (best; mediocre; poorest). The resulting scores are represented thus in Figure 5.3. To examine these differences statistically, a (3 x 3) ANOVA was conducted on the number of hearings data. Orthogonal planned contrasts tested the main effects and interactions of the pattern metricality and quality of rhythm sets factors (see Appendix 5.9). Alpha was set at .05, and the critical value for F(1,3) is 10.13.

The ANOVA revealed a significant main effect of pattern metricality. More hearings were required for nonmetrcial patterns than for quadruple and triple patterns when making metricality judgements, F(1,3) = 14.68 (see Figure 5.3). However, the difference in number of hearings required to judge quadruple and triple patterns was not reliable, F(1,3) = 8.98.

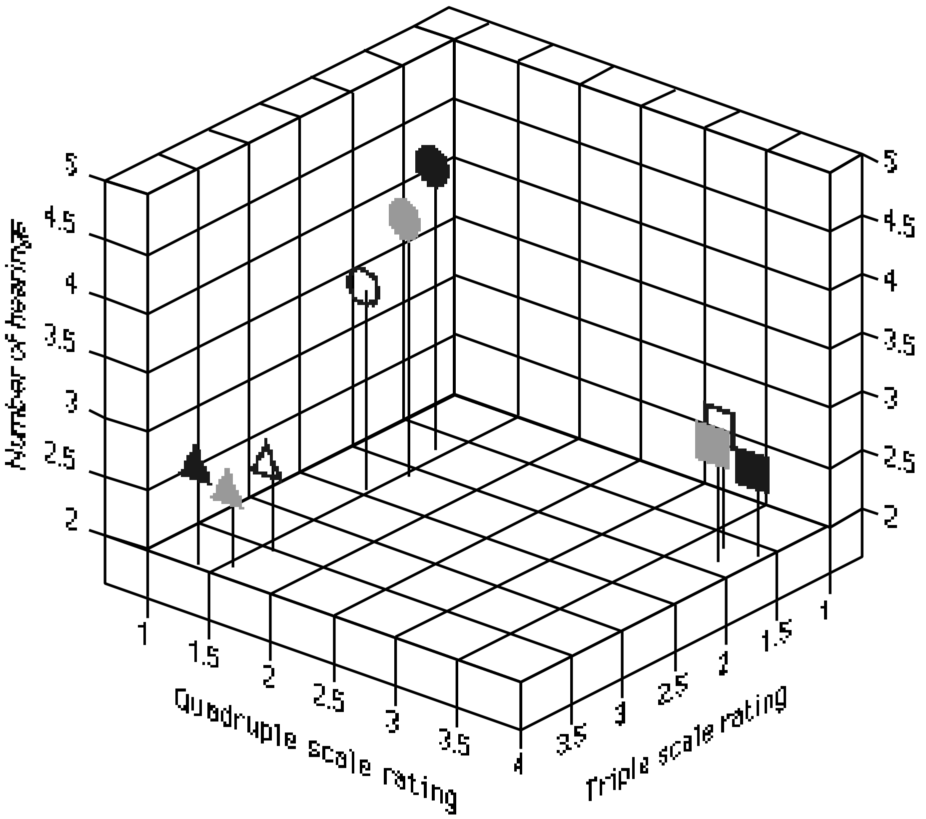



**Figure 5.3:** Average metricality ratings (on triple and quadruple scales) and number of hearings for triple (Δ), quadruple (□), and nonmetrical (O) integrant patterns from best (filled black), mediocre (filled grey), and poorest (unfilled) rhythm sets. The three-dimensional representation allows the relationship between perceived metricality and number of hearings to be seen.

There were no reliable main effects of quality of rhythm sets: linear and quadratic trends were not significant. There was, however, a significant interaction between metricality and the linear trend across the three quality groups. The linear trend for number of hearings across rhythm set quality is clearer for nonmetrical patterns than for metrical patterns, F(1,3)

= 14.50 (see Figure 5.3). This suggests that perceived metricality, or rhythmic complexity, has more effect upon auditory inspection time in nonmetrical than in metrical patterns. The quadratic trend across quality of rhythm sets did not interact significantly with metricality.

#### 5.2.2.6 Discussion

Overall, results are informative about the validity of the theoretical metricality classification scheme described in section 4.4.4, and about the relationship between perceived metricality and processing efficiency. Findings support the psychological reality of the classification of patterns as quadruple, triple, and nonmetrical, and indicate that patterns from these theoretical categories were processed with differential levels of efficiency.

Metricality judgements, reflecting the degree to which patterns from different theoretical metricality categories fit quadruple and triple interpretive frameworks, suggest that there is considerable correspondence between theoretical and perceived metricality. Quadruple integrant patterns and aggregate patterns were judged by musical experts to fit a quadruple meter better than they fit a triple meter when presented auditorily. Nevertheless, varying levels of metrical ambiguity were observed with quadruple patterns, especially aggregate patterns, from some rhythm sets. The metricality ratings for these ambiguous patterns indicated that they were interpetable according to a triple framework, although metricality ratings were higher in all cases for judgements according to a quadruple framework. Similar results were obtained with triple integrant patterns. All triple integrant patterns were judged to fit a triple meter better than they fit a quadruple meter. Although metrical ambiguity was evident in triple integrant patterns from some rhythm sets, it appeared to be less pronounced than the ambiguity associated with quadruple integrant patterns. The tendency for greater ambiguity in quadruple integrant patterns than in their triple counterparts is difficult to explain because it seems to go against the assumption that Western listeners are biased towards quadruple interpretations (but note that ternary biases have existed earlier in history – see 3.3.3.1.1).

Notable departures from theoretical predictions occurred in the case of nonmetrical patterns. Expert musicians indicated that nonmetrical integrant patterns from approximately half the rhythm sets are interpretable according to a triple framework. At first glance, this appears to be consistent with the findings of the autocorrelation analysis of patterns (see Appendix 4.6), which revealed periodic components implying a triple meter in some theoretically nonmetrical patterns. However, the number of nonmetrical patterns that were judged to be metrical in the present experiment (19) far exceeds the number of deviant (target) nonmetrical patterns identified in the autocorrelation study (4). Furthermore, there is very little correspondence between which nonmetrical patterns have elements of periodicity and which were judged to be metrical (only a single pattern – from rhythm set 23 – meets both criteria). This highlights the difficulty in defining metricality objectively: subjective factors such as biases towards metrical interpretations play a large role. The present findings with nonmetrical patterns contraindicate the operation of quadruple preferences, and along with the nature of the metrical ambiguity in quadruple patterns, are suggestive of a triple bias instead.

In ad-hoc interviews (conducted several days following testing and after data had been subjected to preliminary analyses), experts reported two chief strategies through which they achieved metrical interpretations of theoretically nonmetrical patterns. One strategy was to assume that the patterns are characterised by a high level of syncopation, while the other involves alternately lengthening and shortening the interpretive framework's beat interval (as in expressive timing) so as to accommodate the irregularly spaced pattern elements. Both strategies necessitate advanced attending skills: the first requires the proactive generation of robust metric frameworks, whilst the second requires considerable flexibility in metric framework use. Therefore, it is perhaps doubtful that triple interpretations of the theoretically nonmetrical patterns would arise spontaneously (i.e., reactively) when listening to the patterns, and in participants with less musical skill.

Although the metricality judgement task does not measure representational efficiency per se, it provides some indication of the potential for patterns to be represented efficiently according to metric frameworks. Present findings suggest that this potential varies considerably across the 36 rhythm sets. It is not only the case that theoretically metrical patterns generally hold greater potential than theoretically nonmetrical patterns for efficient representation, but also that patterns from some rhythm sets are more likely to be represented efficiently than patterns from other rhythm sets. It is currently assumed that the ordering of rhythm sets based on metricality scores reflects the variation in potential for representational efficiency. This ordering also has implications for processing efficiency.

Auditory inspection time was found generally to decrease with increasing metricality. Increases in the degree to which theoretically metrical patterns were perceived to conform to their best fitting metric framework were accompanied by decreases in the number of hearings required to make metricality judgements. However, increases in the degree to which these patterns were perceived to conform to the framework other than their best fitting framework (i.e., increases in metrical ambiguity) were associated with increasing numbers of hearings. This reciprocity in the relationship between metricality and auditory inspection time was clearly evident in quadruple and triple integrant patterns, and also characterised aggregate patterns, albeit to a lesser degree due to their ambiguity. This suggests that, for metrical patterns, the processing operations recruited when making metricality judgements become more efficient as metricality increases (or rhythmic complexity, including ambiguity, decreases).

The relationship between metricality, or rhythmic complexity, and processing efficiency is cloudy in the case of theoretically nonmetrical patterns. Contrary to expections, it was found that auditory inspection time increased with increases in the degree to which these patterns were judged to fit a quadruple meter. This mirrors the results with triple patterns and perhaps reflects the triple interpretive bias discussed earlier. Alternatively, these findings may indicate simply that increasing auditory inspection time leads to an enhanced impression of metricality. The strategies employed by experts to accommodate theoretically nonmetrical patterns within metric frameworks may require a relatively large number of hearings to be implemented effectively. This explanation, though intuitively appealing, is questionable because an equivalent effect failed to occur when fit to a triple meter was under evaluation.

A better understanding of findings for patterns from all theoretical metricality categories is gained by considering the relationship between processing efficiency and the more comprehensive index of perceived metricality provided by metricality scores, wherein judgements according to quadruple and triple frameworks are combined. This was addressed in the analysis examining the effects of the quality of rhythm sets (reflecting degree of correspondence between theoretical and perceived metricality) upon the relationship between metricality and auditory inspection time.

Across all rhythm set quality groups – best (high correspondence between theoretical and perceived metricality), mediocre, and poorest (low correspondence between theoretical and perceived metricality) – less auditory inspection time was required to judge metricality when patterns were metrical (quadruple or triple) than when they were nonmetrical. This suggests that metrical patterns are processed more efficiently than nonmetrical patterns. Furthermore, there were qualitative differences in the effects of rhythm set quality upon for metrical and nonmetrical patterns. Rhythm set quality did not affect auditory inspection time reliably in metrical patterns, while it had a marked effect in nonmetrical patterns: in general, the less metrical (or more nonmetrical) these patterns were ultimately judged to be, the more hearings required to make the judgement. This suggests that processing efficiency decreased with increasing rhythmic complexity in nonmetrical patterns more than in metrical patterns. The overall findings of the rhythm set quality analysis imply that auditory inspection time is most sensitive as an index of processing efficiency in nonmetrical patterns.

To conclude, the metricality judgement paradigm yielded findings that basically support the psychological validity of the theoretical metricality scheme underlying the classification of patterns in rhythm sets. Patterns from the quadruple and triple categories were judged to fit their respective metric frameworks, whilst patterns from the nonmetrical category generally inspired lower metricality judgements (although some theoretically nonmetrical patterns were still judged to be metrical). In further support of the theoretical classification, there was indication that metrical patterns were processed more efficiently than nonmetrical patterns. Although promising on the whole, the present findings can be questioned on the grounds of ecological validity, especially the aberrant results with nonmetrical patterns. Judging metricality is an artificial task in which the strategies used to process and represent patterns are constrained by the pre-specified interpretive frameworks. To make metricality judgements, the nominated metric frameworks must be generated proactively and sustained regardless of the degree to which they are violated by a target pattern's structure. These feats require declarative knowledge of the concept of meter and considerable skill in metric framework generation. Real-world musical interactions, including both listening and performing, do not necessarily require such knowledge and skill. Therefore, Singlepart Experiment 2 examines the psychological validity of metricality classifications with less skilled participants in a task that does not require explicit knowledge and use of metric frameworks.

## 5.3 Singlepart Experiment 2: Metrical context effects

### 5.3.1 Introduction

Singlepart Experiment 2 investigates processing and representational efficiency in rhythmic behaviour by examining (a) auditory inspection time and (b) the effects of metrical context on recognition memory for metrical and nonmetrical patterns. The experimental paradigm that is employed involves a series of pattern exposure phases, each followed immediately by a recognition memory test phase. Auditory inspection time is measured during exposure phases, and metrical context effects are gauged during test phases.

In each exposure phase, listeners are required to memorise a rhythm pattern that, as in Singlepart Experiment 1, either best fits a quadruple meter, best fits a triple meter, or is nonmetrical. In order to investigate further the psychological reality of the metricality classification scheme underlying the specially constructed rhythm sets, the same patterns that were used in Singlepart Experiment 1 serve as stimuli. As was the case in Singlepart Experiment 1 listeners are permitted to hear patterns as many times as required to memorise them in the current procedure.

In recognition test phases, listeners rate the degree to which they are confident that target (same) and distracter (different) patterns are the same as, or different to the pattern in the preceding exposure phase. In each test phase, target and distracter patterns are presented in one of six possible contexts. Two of these are full metrical contexts, with isochronous sequences marking bar- and beat-level pulsations of either a quadruple or a triple meter. The remaining contexts are included for control purposes. In three control contexts, isochronous sequences articulate either only bar-level pulsations (quadruple or triple) or only beat-level pulsations. Pulsation markers are absent in the final control context, leaving test patterns unaccompanied. This final condition allows baseline performance to be established, against which the effects of the contexts with markers can be assessed.

This procedure does not require that listeners possess declarative knowledge about metric frameworks, unlike the metricality judgment paradigm employed in Singlepart Experiment 1. The findings of Singlepart Experiment 1 were taken to indicate that, according to musical experts, the theoretically metrical patterns from the rhythm sets described in section 4.4.4 do indeed hold greater potential to be represented according to metric hierarchies than the nonmetrical patterns from these rhythm sets. The change in task demands from those present in the metricality judgment paradigm, allows the current experiment to address whether this potential is realised by average listeners who lack sophisticated knowledge of music theory.

The present study differs from earlier studies of metrical context effects (e.g., Palmer & Krumhansl, 1990; Povel & Essens, 1985) in that contextual cues are provided at retrieval rather than at encoding. Supplying metrical contexts during encoding may introduce artificial biases into how rhythm patterns are processed and represented, because metrical cues are often impoverished or absent in real musical presentations. Providing various contextual cues only during recognition memory test phases in the current paradigm should allow insight into how patterns are encoded and represented in memory under relatively naturalistic conditions.

It is expected that if the metricality classification scheme underlying the constructed rhythm sets is valid, then results should indicate that metrical patterns are processed and represented more efficiently than nonmetrical patterns. As evidence of processing efficiency, nonmetrical patterns should need to be heard more times than metrical patterns during memorisation. Furthermore, musicality should affect processing efficiency: musically skilled listeners should require less hearings overall than unskilled listeners. It is also expected that metrical patterns in general will be recognised more accurately than nonmetrical patterns. This difference should be more evident in musicians, as they should be more proficient at using metric frameworks. Furthermore, despite the results of Singlepart Experiment 1 (where a triple bias was found), it is expected, based on the discussion of metric preferences in section 3.3.3, that recognition accuracy will be greater with quadruple patterns than with triple patterns, especially for musicians.

The type of context accompanying memory test items is also expected to affect accuracy. In accordance with ideas related to the encoding specificity principle (Tulving & Thomson, 1973), providing appropriate metrical contexts should facilitate the recognition of patterns that are represented efficiently according to metrical hierarchies. Specifically, recognition accuracy should be greatest for quadruple patterns in the full quadruple context and triple patterns in the full triple context. Metrical context is not expected to affect the recognition of nonmetrical patterns, as they should not be represented according to metric hierarchies in the first place. Examining performance in control contexts, where bar- and beat-level components of ideal metric hierarchies are either absent or presented in isolation, will allow the necessary structural elements of metric representations to be discerned. It is expected that for metrical patterns performance in their appropriate full metrical contexts (consisting of bar- and beat-level pulsation markers) will be superior to performance in control contexts (consisting of either only bar- or beat-level markers). This difference is expected to be smaller for musicians than nonmusicians because the former should have access to stronger internalised frameworks.

## 5.3.2 Method

### 5.3.2.1 Participants

Twenty-four first year psychology students from the University of NSW volunteered to participate in Singlepart Experiment 2. Twelve of these comprised the musician group, and 12 were nonmusicians. The main criteria for musicans was more than six years instrumental experience, and the criteria for nonmusicians were not to have played an instrument in the past three years and, pior to that period, to have less than three years instrumental experience. Musicians had, on average, 7.83 years of instrumental experience, and had received about 7 years of formal training on their instrument and 2.3 years of training in music theory. By contrast, nonmusicians had only an average of 2.89 years of instrumental experience, and had received only 2.25 years of formal instrumental training and 0.5 years of training in music theory. Median age was 18.5 years for musicians and 19.5 years for nonmusicians.

### 5.3.2.2 Design

A 2 x 3 x (3 x 6 x 3) factorial design was employed. The between groups factors were *musicality* (musician; nonmusician) and *subgroup* (subgroup-*a*; subgroup-*b*; subgroup-*c*). The within group factors were *pattern metricality* (triple; quadruple; nonmetrical), *context* (quadruple metrical; triple metrical; quadruple bar-level markers; triple bar-level markers; beat-level markers; no markers), and *test pattern type* (target; distracter-$x_i$; distracter-$y_i$). The factorial combination of *pattern metricality* and *context* resulted in 18 experimental conditions. For each of these, the dependent variables – processing efficiency and representational efficiency – were indexed by number of hearings required to memorise patterns during *exposure phases*, and the recognition ratings of target and distracter patterns in different metrical contexts during *memory test phases*, respectively.

Musicians and nonmusicians were each allocated randomly into one of three subgroups. Subgroup allocation determined which rhythm sets would be the source of quadruple, triple, and nonmetrical stimulus patterns, and which contexts would be paired with which patterns. Subgroups were unique in terms of (a) whether the stimulus pattern representing a particular rhythm set was quadruple, triple, or nonmetrical, and (b) which of the six contexts was paired with each of these stimulus patterns. Thus, each subgroup accounted for the 18 experimental conditions with a different combination of rhythm set, pattern metricality, and context. That is, the pattern representing each rhythm set was either quadruple, triple, or nonmetrical, and associated with only one of the six contexts, within subgroups (see Appendix 5.10). The subgroup factor was included (a) to ensure that individual participants did not encounter more than one target integrant pattern from each rhythm set, as patterns within any given rhythm set were composed of identical rhythmic figures despite their metricality (see 4.4.4.2.1), and (b) to allow coverage and item analyses of the rhythm sets.

#### 5.3.2.3 Stimuli and Apparatus

Stimuli for exposure phases were target integrant patterns from the 36 rhythm sets. The rhythm sets were constructed (see 4.4.4.1) such that one target integrant pattern best fits a *quadruple meter*, one best fits a *triple meter*, and one is *nonmetrical*. For memory test phases, six versions of each of these target patterns, and their related distracter-$x_i$ and distracter-$y_i$ patterns, were created in which each pattern is paired with a different one of six contexts. In distracter-$x_i$ patterns, the second of five rhythmic figures was shifted back by two time units relative to its position in its related target pattern. In distracter-*y* patterns, the third rhythmic figure was delayed by two time units. In other words, there was a deviation near the middle of the pattern in distracter-$x_i$ patterns, whereas the deviation occurred nearer to the beginning of the pattern distracter-$y_i$ patterns (see 4.4.4.2.2). A sampled wood block sound was used to articulate target and distracter patterns.

Of the contexts that were paired with the target and distracter patterns, two are *metrical contexts* and four are *control contexts*. In full metrical contexts, context markers defining bar-level and beat-level components of hypothetical metric frameworks occur concurrently with target and distracter patterns (see Figure 5.4, Panels A & B, and Tracks 42-47). The *quadruple metrical* context consists of bar-level and beat-level markers defining a quadruple meter. In the *triple metrical* context, bar- and beat-level markers define a triple meter. Control contexts were produced by progressively stripping levels from the metrical contexts (see Figure 5.4, Panels C, D, E, & F, and Tracks 48-59). Only quadruple bar-level markers remain in the *quadruple bar-level* control context, whereas only triple bar-level markers remain in the *triple bar-level* control context. The *beat-level* control context contains only beat-level markers and the *no markers* control context is characterised by the absence of both bar- and beat-level markers (i.e., test patterns are unaccompanied). A bongo drum sound was used to articulate bar-level markers in all contexts where they appeared. Beat-level markers, when present, were articulated by a hi-hat cymbal sound. Thus, target and distracter pattern elements (wood block sounds), and bar- and beat-level context markers (bongo and cymbal sounds, respectively), were distinguishable on the basis of timbre. The three types of sounds also differed in terms of loudness. The woodblock sound was assigned a MIDI velocity value of 96, the bongo was given a value of 48, and the cymbal a value of 16. Participants were given the opportunity to adjust the loudness level of the woodblock if it was not comfortable (such adjustment led to corresponding changes to the bongo and cymbal sounds, such that the ratio of relative loudness between the three was preserved). None of the participants felt the need to adjust loudness.

Apparatus consisted of AKG headphones and MAX software running on a Macintosh computer, as described in section 4.4.3.

**A: Quadruple metrical context**

```
                     c---------------c---------------c---------------c
Context markers →    c---c---c---c---c---c---c---c---c---c---c---c---c
Quadruple pattern →  x-----------x---x--------------xx-------x---x-x-x

                     c---------------c---------------c---------------c
Context markers →    c---c---c---c---c---c---c---c---c---c---c---c---c
Triple pattern →     x-------x---x----------xx-----------x-------x-x-x

                     c---------------c---------------c---------------c
Context markers →    c---c---c---c---c---c---c---c---c---c---c---c---c
Nonmetrical pattern → x---------x---x-----------xx-----------x----x-x-x
```

**B: Triple metrical context**

```
                     c-----------c-----------c-----------c-----------c
Context markers →    c---c---c---c---c---c---c---c---c---c---c---c---c
Quadruple pattern →  x-----------x---x--------------xx-------x---x-x-x

                     c-----------c-----------c-----------c-----------c
Context markers →    c---c---c---c---c---c---c---c---c---c---c---c---c
Triple pattern →     x-------x---x----------xx-----------x-------x-x-x

                     c-----------c-----------c-----------c-----------c
Context markers →    c---c---c---c---c---c---c---c---c---c---c---c---c
Nonmetrical pattern → x---------x---x-----------xx-----------x----x-x-x
```

**C: Quadruple bar-level context**

```
Context markers →    c---------------c---------------c---------------c
Quadruple pattern →  x-----------x---x--------------xx-------x---x-x-x

Context markers →    c---------------c---------------c---------------c
Triple pattern →     x-------x---x----------xx-----------x-------x-x-x

Context markers →    c---------------c---------------c---------------c
Nonmetrical pattern → x---------x---x-----------xx-----------x----x-x-x
```

**D: Triple bar-level context**

```
Context markers →    c-----------c-----------c-----------c-----------c
Quadruple pattern →  x-----------x---x--------------xx-------x---x-x-x

Context markers →    c-----------c-----------c-----------c-----------c
Triple pattern →     x-------x---x----------xx-----------x-------x-x-x

Context markers →    c-----------c-----------c-----------c-----------c
Nonmetrical pattern → x---------x---x-----------xx-----------x----x-x-x
```

**E: Beat-level context**

```
Context markers →    c---c---c---c---c---c---c---c---c---c---c---c---c
Quadruple pattern →  x-----------x---x--------------xx-------x---x-x-x

Context markers →    c---c---c---c---c---c---c---c---c---c---c---c---c
Triple pattern →     x-------x---x----------xx-----------x-------x-x-x

Context markers →    c---c---c---c---c---c---c---c---c---c---c---c---c
Nonmetrical pattern → x---------x---x-----------xx-----------x----x-x-x
```

**F: No markers context**

```
Quadruple pattern →  x-----------x---x--------------xx-------x---x-x-x

Triple pattern →     x-------x---x----------xx-----------x-------x-x-x

Nonmetrical pattern → x---------x---x-----------xx-----------x----x-x-x
```

**Figure 5.4:** Quadruple, triple, and nonmetrical target patterns (from a single rhythm set) in quadruple metrical (Panel A), triple metrical (Panel B), quadruple bar-level (Panel C), triple bar-level (Panel D), beat-level (Panel E), and no markers (Panel F) contexts.

#### 5.3.2.4 Procedure

Participants were tested individually at the computer in a small sound attenuated chamber. Testing took place over three experimental sessions, each of approximately 45 min duration and separated by no longer than one week. At the beginning of the first session, the participant filled out the musicality questionnaire (see 4.4.2 and Appendix 4.1), and received a training exercise that consisted of detailed instructions (see Appendix 5.11) and an opportunity to practice the task.

In the training exercise, the participant was familiarised with the procedure by instructions presented on the computer screen. These instructions were interactive in the sense that they actively guided the participant through the procedure step by step. Thus, the participant was given a chance to practice the task of memorising a pattern, and then rating whether test patterns presented in a particular context were the same as, or different to, the memorised pattern. After training, the participant was given three practice trials in random order. The target pattern in each practice trial was either quadruple, triple, or nonmetrical. All three types of pattern, and a variety of contexts, were encountered across the three practice trials. All patterns used in the training exercise and practice blocks were presented at a rate with a corresponding time unit duration of 150 ms.

Each of the three experimental sessions consisted of 12 trials (i.e., 36 trials in total). Each trial contained an exposure and a memory test phase. In exposure phases, the participant was presented either a quadruple, a triple, or a nonmetrical pattern, depending on the experimental condition. Four trials in each session contained quadruple patterns, four contained triple patterns, and four contained nonmetrical patterns. Trial order was randomised and presentation rate varied between blocks (see 4.4.4.3.1).

Pressing the space bar on the computer keyboard triggered a single pattern presentation. The participant was instructed to listen to the pattern as many times as was required to memorise it – they simply had to press the space bar on the computer to rehear the pattern. The number of times required to memorise each pattern was recorded by the computer. The memory test phase began when the participant indicated, by clicking a designated area on the computer screen, that they had memorised the pattern.

In the memory test phase, the participant rated the degree to which they were confident that one target, one distracter-$x_i$, and one distracter-$y_i$ pattern was the same as, or different to the pattern presented in the preceding exposure phase. The order in which the three memory test patterns were presented was randomised. During each trial, the memory test pattern was accompanied by a particular one of the six contexts. Each context appeared in two of the 12 trials in each experimental session such that, across the three experimental sessions, each participant encountered two quadruple, two triple, and two nonmetrical target patterns in each of the six contexts. Thus, the 18 experimenal conditions (3 levels of metricality x 6 contexts) were covered, with two exemplars per condition. Pairings of contexts with exemplars of patterns from particular rhythm sets were determined by the subgroup to which the participant had been allocated randomly.

To hear each memory test item, the participant was required to press the space bar. Each test item was presented only once. After each test item, a six-point rating scale automatically appeared on the computer screen (see Appendix 5.11). The participant indicated on this scale the degree to which they were confident that the test pattern itself (not the context) was the same as, or different to, the pattern presented during the exposure phase. To register a rating, the participant was required to click with the computer mouse on a coloured button on the computer screen, and then click a designated area on the screen to progress to the next item (or next trial if the current one was ending) when satisfied with their rating.

#### 5.3.2.5 Analyses

Data of interest were (a) the number of times participants chose to hear patterns during the exposure phases (auditory inspection time), and (b) same/different confidence ratings produced for memory test patterns. Number of hearings data were analysed in a conventional (i.e., using participants as the random variable) 2 x 3 x (3) ANOVA examining the effects of musicality, subgroup, and pattern metricality (see Appendix 5.12). In addition, an item analysis was carried out on the number of hearings data to determine whether the effects of metricality generalise across token patterns from different rhythm sets (see Appendix 5.13). In this item analysis, the random variable was rhythm sets rather than participants. That is, the effects of musicality and metricality upon auditory inspection were assessed by examining variability in responses due to structural differences in patterns that belong to the same theoretical metricality category, but come from different rhythm sets. The main benefit of item analyses is that they provide a means of testing statistically whether results generalise beyond the specific stimulus materials used in a particular experiment (see Clark, 1973, and Foster & Dickinson, 1976, for discussions of the merits of item analyses).[15]

Ratings data were analysed first in a 2 x 3 x (3 x 3) ANOVA examining the effects of musicality, subgroup, pattern metricality, and test pattern type (see Appendix 5.14), and then in a 2 x 3 x (3 x 6 x 2) ANOVA examining the effects of musicality, subgroup, pattern metricality, context and test pattern type (see Appendix 5.15).[16] The difference between these two analyses is that in the first, context effects are not examined and there are three levels of test pattern type (target, distracter-$x_i$, distracter-$y_i$), whereas in the second, context effects are considered, but there are only two levels of test pattern type (target, distracter: i.e., distracter-$x_i$ and distracter-$y_i$ are collapsed). For the purpose of specifying planned contrasts in the second analysis, data were partitioned according to whether context markers were consistent or inconsistent with pattern metricality. For quadruple patterns, the quadruple metrical, quadruple bar-level, and beat-level contexts were defined as consistent, whereas the triple metrical and triple bar-level contexts were defined as inconsistent. For triple patterns, triple metrical, triple bar-level, and beat-level contexts were designated consistent, and quadruple metrical and quadruple bar-level contexts were designated inconsistent. In the case of nonmetrical patterns, all contexts were treated as both consistent and inconsistent to enable full comparisons to be made with metrical patterns. Ratings data were not subject to item analyses because in experimental trials rhythm set, metricality, and context were not combined exhaustively.

In all ANOVAs, the constrasts tested were planned and orthogonal. Alpha was set at .05. In the conventional analyses, the critical value for $F(1,18)$ is 4.41. In the item analysis, the critical value for $F(1,66)$ is 4.00.

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[15] In this, and subsequent experiments, an effect is assumed to be reliable if either the conventional analysis or the item analysis yields a significant result for a particular comparison. Clark (1973) advises that significance should be determined properly by computing a combined F-value for conventional and item analyses. This may be considered to be a fairly conservative approach, and, one that is not routinely followed these days by word reading researchers. Indeed, the majority of researchers in areas other than word reading do not even run item analyses routinely.

[16] These analyses were run separately because the number of contrasts needed to make all the necessary comparisons in this rather large design exceeded memory limits set by the analysis program *WinPsy32 Version 2.0*. Despite these limitations, *WinPsy32* has the advantage over other analysis software that it allows a great deal of flexibility in testing user-specified planned contrasts.

## 5.3.3 Results

### 5.3.3.1 Auditory inspection time

The two ANOVAs carried out upon number of hearings data (the conventional analysis with 'participants' as the random variable, and the item analysis) had different outcomes. Only one significant main effect emerged from the conventional analysis. Musicians and nonmusicians both required less hearings to memorise quadruple patterns than triple patterns, $F(1,18) = 5.50$.

However, the item analysis revealed that, in addition to the quadruple versus triple effect, there were significant main effects of both musicality and metricality (metrical versus nonmetrical). These effects are illustrated in Figure 5.5. Overall, musicians listened more times than nonmusicians to exposure patterns, $F(1,66) = 15.09$. This finding is at odds with predictions, and may reflect differences in listeners' motivation, rather than ability.[17] Perhaps musicians produced a greater number of hearings because they were more determined than nonmusicians to perform well at the task.

Unlike the effects of musicality, the metricality effects revealed by the item analysis are consistent with predictions. Metrical patterns required less hearings than nonmetrical patterns, $F(1,66) = 8.05$, and, once again, quadruple patterns required less hearings than triple patterns, $F(1,66) = 18.55$. However, there were no significant differences in auditory inspection time due to interactions between musicality and metricality.

The nature of the disparity between the conventional and the item analyses suggests that the majority of variability in the data is due to participants rather than items.

[17] It should be noted that a significant effect in an item analyses may arise due to a single individual participant. Indeed, inspection of each participant's data in Appendix 5.12 reveals an unusually high number of hearings for participant 8 in the musician group.

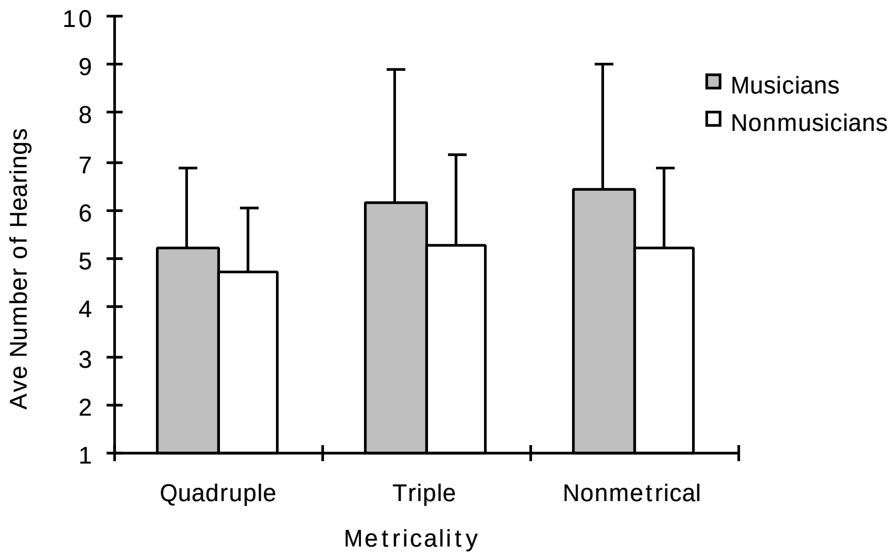


**Figure 5.5:** Musicians' and nonmusicians' auditory inspection time (average number of hearings) when memorising quadruple, triple, and nonmetrical patterns.

### 5.3.3.2 Recognition accuracy

#### *5.3.3.2.1 Effects of musicality, metricality, and test pattern type*

The 2 x 3 x (3 x 3) ANOVA carried out upon ratings produced by listeners during recognition memory test phases revealed significant main effects of musicality ($F(1,18) = 8.21$), metricality – quadruple versus triple ($F(1,18) = 7.27$), and test item type – targets versus distracters ($F(1,18) = 79.36$). The main effect of subgroup was not significant, nor were its interactions with musicality, and test pattern type. This is a desirable outcome: it indicates that recognition accuracy was not affected by which particular exemplars of quadruple, triple, and nonmetrical patterns were encountered.[18]

The main effects of musicality and metricality are not particularly informative alone, but the effect of test item type (target patterns generally received higher ratings than distracter

[18] In the case of subgroup, no meaningful a priori planned contrasts can be generated. Rather, as subgroup should not have any effect upon the results if sampling of stimulus items is truly random, it is hypothesised that there should be no significant effect of any possible comparison of subgroups. In order to test this hypothesis, an overall omnibus F-value for subgroup (rather than F-values for specific comparisons) is required, and for the hypothesis to be supported this should not be significant. Within *WinPsy32* this omnibus F-value was computed by (a) adding the Sum of Squares for each of a complete (k-1) set of orthogonal subgroup comparisons, (b) adding the degrees of freedom values for the same comparisons, (c) dividing the value in [a] by the value in [b] to obtain the Mean Square Error, and (d) dividing the Mean Square Error from [c] by the total Mean Square Error. This procedure was also carried out in all subsequent experiments. Omnibus F-values are reported only if they indicate that subgroup or its interactions with other factors were significant, because it is only under these circumstances that it can be claimed that subgroup affects recognition accuracy.

patterns) indicates that listeners were able to perform the recognition task with a greater than chance level of accurcacy. More interesting is how test pattern type interacts with musicality and metricality. In accordance with predictions, there was a significant interaction between musicality and test item type (targets versus distracters), F(1,18) = 8.83, indicating that ability to distinguish between target and distracter patterns, hence recognition accuracy, was greater in musicians than nonmusicians (compare Panels A & B in Figure 5.6). Furthermore, the interaction between metricality (metrical versus nonmetrical) and test pattern type (targets versus distracters) was significant, F(1,18) = 42.19. This result indicates that metrical patterns were recognised more accurately than nonmetrical patterns. However, contrary to predictions, the interaction between musicality, metricality (metrical versus nonmetrical), and test pattern type (targets versus distracters) was not significant, F(1,18) = 1.72. That is, musicians and nonmusicians exploited the advantages of metrical structure to a similar degree.

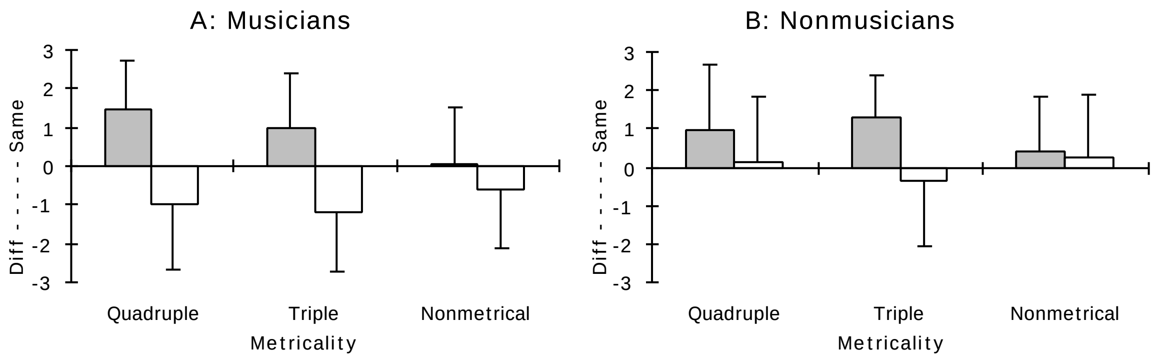


**Figure 5.6:** Musicians' (Panel A) and nonmusicians' (Panel B) recognition memory accuracy for quadruple, triple, and nonmetrical patterns. Filled grey bars represent average same/different confidence ratings for target patterns. Unfilled bars represent ratings for distracter patterns.

Also contrary to predictions, no significant differences were observed between accuracy for quadruple and triple patterns, F(1,18) = 1.51. Nevertheless, the interaction between musicality, metricality (quadruple versus triple) and test item type (targets versus distracters) was significant, F(1,18) = 5.33 (see Figure 5.6). Musicians recognised quadruple patterns better than triple patterns, whereas nonmusicians were more accurate with triple than quadruple patterns. This might suggest that musicians have more deeply ingrained preferences for the quadruple structure.

Interestingly, type of distracter pattern was found unexpectedly to affect accuracy. There was a significant interaction between metricality (metrical versus nonmetrical) and test item type (distracter-$x_i$ versus distracter-$y_i$), F(1,18) = 10.08 (see Figure 5.7). When target patterns were metrical, listeners produced lower ratings (indicating more confident 'different' judgements) for distracter-$y_i$ patterns than distracter-$x_i$ patterns, whereas the opposite occurred with nonmetrical target patterns. Distracter-$x_i$ and distracter-$y_i$ patterns differ in terms of the location of the temporal deviation that distinguishes them from their related target pattern. These deviations occur during the first half of the pattern in distracter-$x_i$ patterns, and during the second half in distracter-$y_i$ patterns. Therefore, this finding suggests that, when comparing distracter patterns to metrical targets, listeners were better at detecting late deviations (a recency effect), but with nonmetrical target patterns, they were more sensitive to early deviations (a primacy effect). Metric frameworks may help sustain attention for the full duration of the pattern.

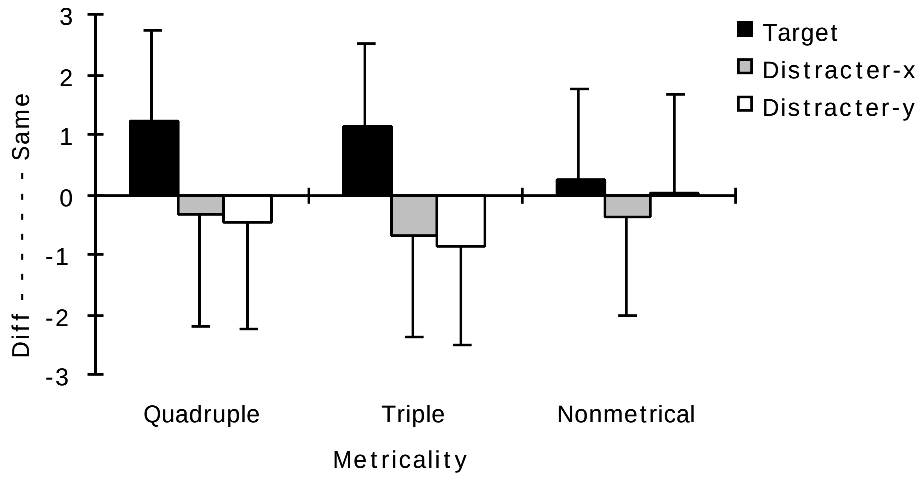


**Figure 5.7:** Recognition accuracy for quadruple, triple, and nonmetrical patterns.

### *5.3.3.2.2 Context effects*

The 2 x 3 x (3 x 6 x 2) ANOVA revealed that the presence of context markers affected listeners' ratings of target and distracter memory test patterns in various ways. Ratings were generally lower in conditions where test patterns were accompanied by context markers (quadruple metrical; triple metrical; quadruple bar-level markers; triple bar-level markers; beat-level markers) than in the condition where patterns were unaccompanied (no markers). This effect occurred whether or not the accompanying contexts were consistent or inconsistent with target patterns, $F(1,18) = 18.71$ and $7.95$, respectively (compare Panels A & B with Panel C in Figure 5.8). This suggests that test patterns – regardless of type (target, distracter-$x_i$, distracter-$y_i$) – were judged by listeners to be less similar to exposure patterns as a consequence of the mere presence of markers.

Moreover, it was found that the presence of context markers affected overall ability to differentiate between target and distracter patterns when the markers were inconsistent with pattern metricality, F(1,18) = 6.13, to a greater degree than when they were consistent, F(1,18) = 0.19 (compare Panels A & B in Figure 5.8). In other words, inconsistent contexts produced greater interference to recognition accuracy. The effect of this intereference was greater when target patterns were metrical than when they were nonmetrical, F(1,18) = 7.20 (compare Panels B & C in Figure 5.8). This selectivity suggests that, in accordance with predictions, the presence of context markers does not affect the perception of nonmetrical pattern structure.

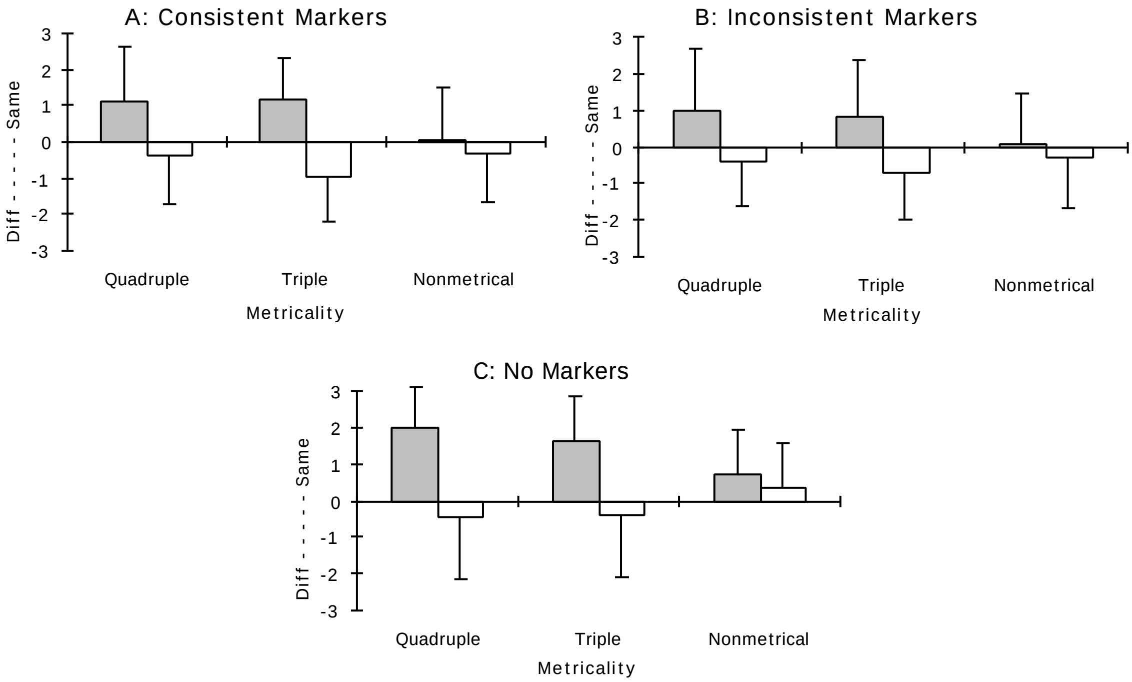


**Figure 5.8:** Recognition accuracy for quadruple, triple, and nonmetrical patterns in contexts with consistent markers (Panel A), inconsistent markers (Panel B), and no markers (Panel C). Average same/different confidence ratings are shown for target (filled grey) and distracter (unfilled) patterns.

Recognition accuracy was also affected by whether contexts included both bar- and beat-level markers, only bar-level markers, or only beat-level markers. Accuracy was superior for patterns tested in full metrical contexts (quadruple metrical; triple metrical) than for patterns tested in contexts with only bar-level markers (quadruple bar-level markers; triple bar-level markers) when context markers and pattern metricality were consistent, F(1,18) = 7.12 (compare Panels A & F with Panels C & H in Figure 5.9), but not when they were inconsistent, F(1,18) = 2.95 (compare Panels B & G with Panels D & I in Figure 5.9). Thus, in accordance with predictions, providing appropriate metrical contexts boosts performance relative to when only partial contextual information is provided, even if the partial cues are consistent with pattern metricality. This effect was found to be more pronounced in nonmusicians than in musicians, $F(1,18) = 6.15$ (compare differences in Panels A & C with those in Panels F & H in Figure 5.9). This suggests that musicians rely to a lesser extent than nonmusicians upon external beat-level cues, presumably because they have access to a more robust internalised beat.

Type of context markers and musicality also impacted upon the metricality effects described earlier (in section 5.3.3.2.1). Differences due to context were observed in the degree to which musicians and nonmusicians displayed superior recognition for metrical patterns over nonmetrical patterns. Only for musicians was there a greater difference in accuracy between metrical and nonmetrical patterns in contexts with appropriate full metrical or bar-level markers, than in contexts with only beat-level markers, $F(1,18) = 7.23$ (compare Panels A & C with Panel E, and then Panels F & H with Panel J, in Figure 5.9). That is, when provided with bar-level markers that are consistent with pattern structure, musicians were better able than nonmusicians to use these markers as cues to recognising target patterns. It seems that musicians are more adept at exploiting cues to higher-level metric pulsations. This effect was absent when context markers were inconsistent with pattern structure, $F(1,18) = 1.02$.

Comparing recognition accuracy for patterns in full metrical and bar-level contexts with accuracy in beat-level contexts also provides evidence that musicians and nonmusicians have different metric preferences. These preferences transpire when accuracy at recognising metrical patterns in contexts that include inconsistent bar-level markers is compared with accuracy in contexts consisting only of beat-level markers. For both musicians and nonmusicians, accuracy is affected to a greater degree when pattern structure is quadruple or triple in beat-level, than in full metrical and bar-level contexts, but, whereas accuracy is better with quadruple patterns for musicians, nonmusicians favour triple patterns, $F(1,18) = 6.21$ (compare Panels B & D with Panel E, and then Panels G & I with Panel J, in Figure 5.9). Thus, a quadruple preference for musicians, and a triple preference for nonmusicians emerged in the presence beat-level markers, but not bar-level markers. Given that the relevant bar-level markers were inconsistent with pattern structure, this result suggests that conflicting cues to meter may interefere with the recognition process. Accordingly, this particular context effect does not occur when cues are consistent with pattern structure, $F(1,18) = 1.31$.

The interference observed in contexts that include inapproprate bar-level markers provides evidence that listeners are using frameworks that include the hypothesised bar-level pulsations. Further evidence is obtained by examining directly how recognition accuracy is affected by whether contextual cues are consistent or inconsistent with pattern metricality. In accordance with predictions, quadruple and triple patterns were recognised better when accompanying cues were consistent than when they were inconsistent, $F(1,18) = 4.87$ (compare Panels A, F, C, & I with Panels B, G, D, I in Figure 5.9, wherein 'Qd' if for quadruple, 'Tr' is for triple, and 'Nm' is for nonmetrical). Specifically, quadruple patterns were recognised better in contexts where markers were consistent with a quadruple meter, than where in contexts where markers suggested a triple meter, whereas the opposite was the case for triple patterns. Thus, recognition accuracy for metrical patterns was affected markedly by switching the surrounding contextual cues. The interaction between consistency of context and musicality was not significant, $F(1,18) = 3.19$, indicating that the 'switch effect' occurred in both musicians and nonmusicians.

The peculiar response patterns in Panels E, H, I, and J of Figure 5.9, which indicate that some target patterns received ratings less than zero and some distracter patterns received ratings greater than zero, are difficult to explain.

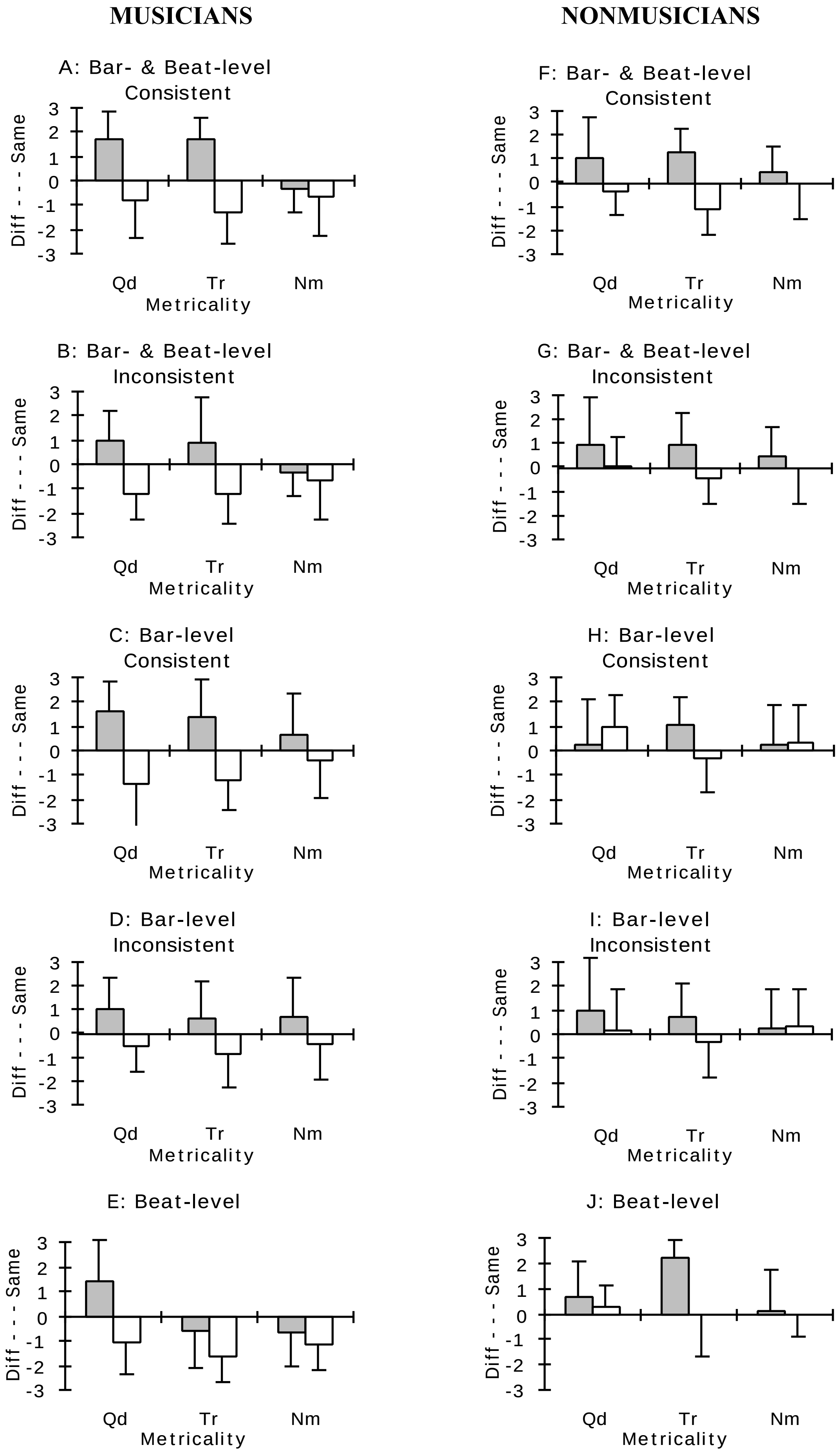


**Figure 5.9:** Recognition accuracy in contexts with markers (grey = target; unfilled = distracter).

### 5.3.4 Discussion

On the whole, results support the proposal that metrical patterns are processed and represented more efficiently than nonmetrical patterns. Findings also indicate that processing and representation are more efficient with quadruple, than triple patterns. Auditory inspection time was longer for metrical patterns than for nonmetrical patterns, and, within the metrical category, for triple patterns than for quadruple patterns. This suggests that the process of encoding was most efficient for quadruple patterns, followed by triple patterns, and then nonmetrical patterns. In support of variations in both processing and representational efficiency due to metricality, it was found that metrical patterns were recognised more accurately than nonmetrical patterns, and that accuracy was greatest with quadruple patterns for musicians, whereas accuracy was greatest with triple patterns for nonmusicians.

However, the strongest evidence for metricality-based differences in representational efficiency comes from the context effect findings. Two findings in particular are revealing in this regard. First, the presence of context markers affected the recognition of metrical, but not nonmetrical patterns, suggesting that metric frameworks are irrelevant to the representation of nonmetrical structure. Second, switching the context in which memory test items were presented affected recognition accuracy such that metrical patterns were recognised better when accompanying context markers were consistent with theoretical metricality, than when they were inconsistent. Specifically, quadruple patterns were recognised best in the presence of quadruple context markers, whereas triple patterns were recognised best in triple contexts. This switch effect suggests that metrical contexts consisting of bar-level and beat-level markers approximate listeners' internal representations of meter.

Taken together, the auditory inspection findings, and findings indicating that metrical context markers affect the recognition of metrical, but not nonmetrical patterns, corroborate the psychological validity of the theoretical metricality scheme used to construct stimulus patterns. The generality of this claim across listeners varying in musical skill was demonstrated through the use of an experimental paradigm that does not require explicit knowledge of the concept of musical meter. Thus, although nonmusicians may not possess the declarative knowledge of meter that usually accompanies musical skill (in Western classical music, at least), they demonstrated procedural knowledge about the use of metric frameworks. However, although findings show that musicians and nonmusicians use metric frameworks in a manner that is generally consistent with the theoretical metricality scheme, some skill-based differences emerged reflecting musicians' greater overall rhythmic ability, and more developed sense of meter.

In favour of greater overall rhythmic abilities in musicians, their recognition memory was generally superior to nonmusicians' recognition memory. Evidence for more sophisticated usage of metric frameworks by musicians lies in findings relating to metric biases and certain context effects. With regard to metric biases, musicians were more accurate at recognising quadruple patterns than triple patterns, whereas the nonmusicians were better with triple patterns. The quadruple bias displayed by musicians may be a product of culture specific musical training, as quadruple structures are more common than triple structures in Western music (see 3.3.3.1). The fact that musicians' sensitivity to quadruple structure in the current experiment appears to be at odds with the triple bias displayed by musical experts in Singlepart Experiment 1 is difficult to explain, but it is not necessarily troublesome because these experiments differed greatly in task demands.

The reasons behind the favouring of triple structures by nonmusicians in the current experiment is less clear, although claims that the 3:1 ratio underlying triple patterns is simpler than the 4:1 ratio underlying quadruple patterns may form part of an explanation (see 3.3.1). Another possible explanation is that ternary division renders patterns more manageable for nonmusicians because it segments overall pattern duration into smaller chunks than those resulting from the quaternary division underlying quadruple meter (i.e., four groups of three beats, as opposed to three groups of four beats).

A relationship between musical skill and a sophisticated sense of meter is evidenced by findings that (a) musicians performed better than nonmusicians in contexts devoid of beat-level markers, and (b) musicians benefited more than nonmusicians when bar-level markers were consistent with theoretical metricality. These findings imply that increasing musical skill is associated jointly with a strengthing of internalised beat-level pulsations and greater facility at exploiting higher bar-level pulsations. Thus, musicians are more adept than nonmusicians at using both levels of pulsation that characterise metric hierarchies.

The skill-based differences observed in overall accuracy and use of metric frameworks are in general consistent with the findings of investigations by other researchers (e.g., Jones & Yee, 1997; Smith & Cuddy, 1989; Yee et al., 1994). Current findings relating to metric biases and context effects expand upon these earlier investigations by showing that when patterns are not particularly rich in cues to meter, skilled listeners are better able than unskilled listeners to form representations of the patterns based on metric hierarchies consisting of beat- and bar-level pulsations. The present finding that overall accuracy is greater in musicians than in nonmusicians is less remarkable because it is offset by the fact that auditory inspection time was greater in musicians. So perhaps the greater recognition accuracy observed in musicians was due to more exposure to target patterns during memorisation phases. It was proposed earlier (section 5.3.3.1) that auditory inspection time may have varied as a function of motivational factors rather than competence. This vulnerability to extraneous variables, along with the (related) fact that auditory inspection time is not a *direct* measure of online processing demands, implies that it is not an ideal measure of processing efficiency. As pointed out in Chapter 4, interference effects in multipart contexts may be a viable alternative. This idea will be explored further in the next chapter by the use of a task that exploits the adavantages of multipart paradigms. The experiments reported in the next chapter also permit the examination of issues such as whether the skill-based differences observed in singlepart contexts transfer to multipart contexts, and, if so, precisely how they are manifest therein.

## 5.4 Singlepart summary

The two singlepart experiments reported in this chapter provide evidence that the efficiency with which rhythm patterns are both processed and represented is enhanced when listeners are given the opportunity to use appropriate metric frameworks. This was demonstrated in Singlepart Experiment 1 using a goodness-of-fit judgement task in which musical experts were required to rate metricality according to pre-specified frameworks, and in Singlepart Experiment 2 using a memory task in which musicians and nonmusicians were required to recognise target patterns when embedded in several different contexts. Both experiments found that efficiency was greater with metrical than with nonmetrical patterns, and, in the case of metrical patterns, when the framework guiding pattern interpretation (which was pre-specified in Singlepart Experiment 1 and reflected by context markers in Singlepart Experiment 2) was consistent with the theoretically best-fitting framework. These findings support the validity of the theoretical metricality classification scheme underlying the construction of patterns in the 36 rhythm sets. It is particularly noteworthy that the classification scheme has psychological reality for listeners who vary widely in terms of musical skill, ranging from nonmusicians to musical experts. The experiments described in the next chapter use patterns from the 36 rhythm sets to investigate how the efficiency associated with metric frameworks benefits behaviour in multipart rhythmic contexts.

# CHAPTER 6

# METER IN ATTENDING TO MULTIPART PATTERNS

Three experiments addressing the role of metric frameworks in multipart musical rhythmic behaviour are reported in this chapter. All experiments test the hypothesis that metric frameworks facilitate prioritied integrative attending in multipart contexts. The first experiment employs a recognition memory paradigm to examine the effects of encoding metrical versus nonmetrical target integrant patterns upon the processing of the aggregate patterns in which they are embedded. The second uses a recognition memory task to study the effects of retrieving target integrant patterns that vary in metricality upon aggregate pattern processing. Finally, the third experiment examines the effects of target integrant pattern metricality upon prioritised integrative attending in a paradigm requiring pattern reproduction.

## 6.1 Multipart aims

The experimental findings reported in the previous chapter indicate that metric frameworks facilitate processing and representational efficiency in the context of singlepart patterns. The experiments described in this chapter test the hypothesis that this efficiency promotes attentional flexibility in the context of multipart patterns. All three multipart experiments here address the relationship between the processing efficiency associated with metric frameworks and ability to engage in prioritised integrative attending. This relationship is examined in each experiment by measuring the degree to which processing target integrant patterns that vary in metricality interferes with the process of attending to the structure of aggregate patterns in which they are embedded. The experiments differ with regard to the stage of processing under examination (encoding or retrieval) and the method used to assess prioritised integrative attending ability (recognition or reproduction).

The first two multipart experiments investigate prioritised integrative attending in listening-based recognition memory tasks. In the first, the efficiency of encoding processes is assessed by examining the effects of target integrant metricality upon ability to simultaneously memorise, and subsequently recognise, both target integrant and aggregate aspects of multipart patterns. The second experiment addresses the efficiency of retrieval processes using a dual task paradigm that requires aggregate pattern structure to be memorised whilst simultaneously accessing memory representations of target integrant patterns that were exposed earlier. Each of these experiments also includes conditions that require either selective attending to target integrant patterns alone, or nonprioritised integrative attending to aggregate patterns. These serve as control conditions allowing the effects of prioritised integrative attending to be gauged. The final multipart experiment examines efficiency at retrieval in a reproduction-based task. This task involves memorising aggregate patterns while concurrently reproducing target integrant patterns that were exposed earlier.

It was hypothesised in Chapter 3 that attentional flexibility in multipart contexts is affected by three factors: multipart rhythmic complexity, musical skill, and attending mode. A graphical summary of the hypothetical effects of these factors was given in Chapter 3, and is reproduced here in Figure 6.1. According to the hypotheses, attending should become less flexible with increasing rhythmic complexity, decreasing musical skill, and increasing attentional demands (e.g., increasing prioritisation of integrative attending). Therefore, it is expected that, across the three multipart experiments, behaviour relating to target integrant and aggregate patterns will be less accurate (a) when target integrant patterns are nonmetrical than when they are metrical, (b) when attenders have low musical skill, and (c) when prioritised integrative attending, as opposed to selective and nonprioritised integrative attending, is required. Furthermore, these effects are expected to be compounded by the interaction of the three factors. Thus, the effects of musicality should be more pronounced at low levels of complexity, for example, when target integrant and aggregate patterns best fit the same meter. This is because, as shown in Singlepart Experiment 2 (see 5.2), sensitivity to metrical structure and proficiency at using metric frameworks are greater in musicians than in nonmusicians. Moreover, the effects of both musicality and complexity should be more pronounced at high levels of prioritisation. This follows from claims made in Chapter 3 that musicians are more experienced than nonmusicians at prioritised integrative attending (e.g., through ensemble performance), and that, when engaged in this mode of attending, it is difficult to overcome challenges associated with rhythmic complexity, such as those presented by nonmetrical patterns.

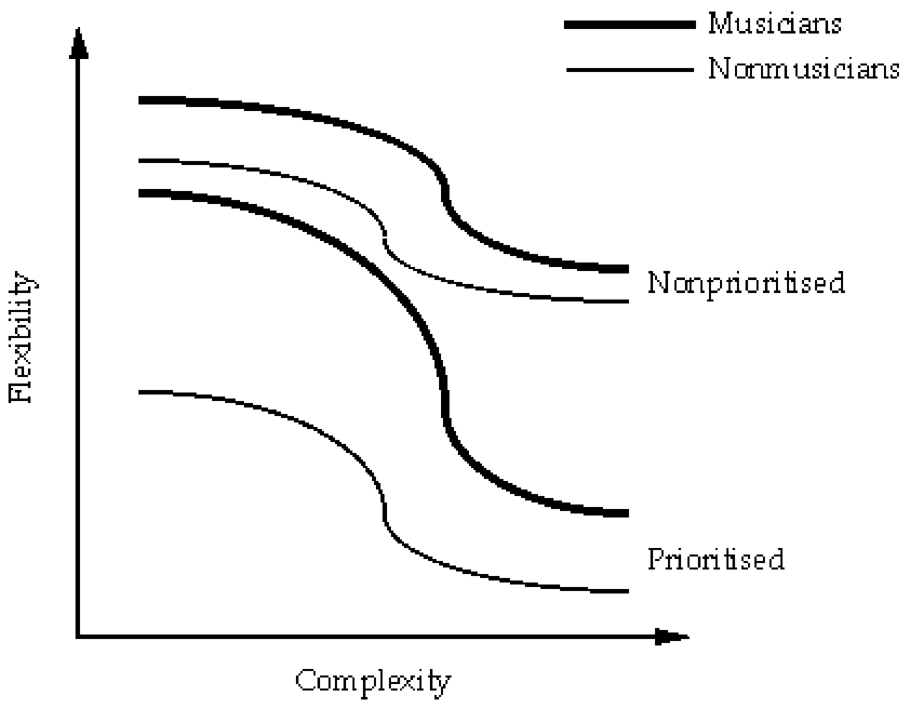


**Figure 6.1:** Hypothetical effects of complexity, musicality, and attending mode upon flexibility revisited.

## 6.2 Multipart Experiment 1: Efficiency at encoding

### 6.2.1 Overview

The process of simultaneously encoding target integrant and aggregate aspects of multipart patterns is a component of prioritised integrative attending in performance- and observation-based musical interactions alike. It was claimed in Chapter 3 that both performers and audience members develop interdependent memory representations for target integrant and aggregate patterns during a performance. For example, the soloist in a concerto and the audience typically are able to recall information jointly about the solo performance (i.e., the target integrant aspect), and the interaction between solo and orchestral accompaniment (i.e., the aggregate aspect). The task of encoding under such prioritised integrative attending conditions is simulated in the present experiment by requiring listeners to simultaneously memorise both target integrant and aggregate aspects of the multipart rhythm patterns described earlier in section 4.4.4. This *prioritised integrative attending condition* is the primary focus of the study, but another two conditions – selective attending and nonprioritised integrative attending – are included for control purposes.

The experimental paradigm involves blocks of trials where, in each trial, listeners are (a) exposed to a multipart pattern composed of a target integrant pattern and a complementary integrant pattern, and then in the prioritised integrative attending condition, (b) tested for recognition memory of either the target integrant, or the aggregate pattern (made up of the sum of the target and complementary integrant patterns). A schematic diagram of the task is given in Figure 6.2. Note that aggregate memory test items are presented as singlepart patterns, rather than multipart patterns. This allows participants' ability to abstract the aggregate structure from each multipart exposure item to be assessed.

To investigate the effects of multipart rhythmic complexity upon ability to engage in prioritised integrative attending, the relationship between target integrant and aggregate patterns was manipulated, as per the description in section 4.4.4, to produce three levels of complexity: (a) *matched metrical* – target and aggregate patterns best fit the same meter; (b) *mismatched metrical* – target and aggregate patterns best fit different meters; (c) *nonmetrical* – the target integrant pattern is nonmetrical, whereas the aggregate pattern is metrical. It is expected that listeners will be successful at prioritised integrative attending to the extent that multipart rhythmic complexity is low. Therefore, recognition memory for target integrant and aggregate patterns should be more accurate in metrical (matched and mismatched) conditions than in nonmetrical conditions. Furthermore, accuracy should be greater in matched metrical, than in mismatched metrical conditions. These differences should be more pronounced for musicians, who are more sensitive than nonmusicians to metrical structure (as indicated by the findings of Singlepart Experiment 2).

**(a) EXPOSURE**

Target integrant x-----------x---x--------------xx-------x---x-x-x
Complementary integrant ------o-o-o---o------ooooooo-oo-----o--o---------

**(bi) MEMORY TEST** **PART TEST**

Target integrant x-----------x---x--------------xx-------x---x-x-x

**(bii) MEMORY TEST** **WHOLE TEST**

Target aggregate v-----v-v-v-v-v-v----vvvvvvv-vvvv---v--vv---v-v-v

**Figure 6.2:** Notated example of a single trial from Multipart Experiment 1 illustrating two possible memory test options. After each exposure in the actual experiment, either the words 'PART TEST' or 'WHOLE TEST' appeared on a computer screen, informing listeners that they should compare the memory test item to the target integrant, or the aggregate pattern, respectively. In this example, the memory test options show target patterns. In the experiment, memory was also tested for distracter integrant and aggregate patterns.

To ascertain the degree to which the anticipated effects of complexity are contingent upon attending mode, the present experiment includes separate conditions requiring *selective attending* and *nonprioritised integrative attending*, in addition to the prioritised integrative attending condition described above.

In the *selective attending condition*, listeners are instructed to attend selectively to, and memorise, only the target integrant aspect of each multipart pattern. In other words, target integrant patterns must be memorised whilst complementary integrant patterns are ignored. It is currently assumed that demands placed upon the listener's attentional resources are less severe with selective attending – a single task where the focus of attention is narrow – than with prioritised integrative attending – a dual task where attention must be spread more widely. Therefore, recognition accuracy for target integrant patterns is expected to be superior in the selective attending condition, relative to accuracy in the prioritised integrative attending condition. Nevertheless, complexity is expected to affect the encoding of target integrant patterns, and their subsequent recognition, similarly with selective and prioritised integrative attending. Therefore, as predicted in the case of prioritised integrative attending, recognition accuracy following selective attending should be greater in metrical conditions than in nonmetrical conditions (especially for musicians). However, whether target integrant and aggregate patterns best fit the same meter is not expected to affect accuracy under selective attending conditions because, if listeners follow task instructions, they should not be encoding aggregate pattern structure. Therefore, accuracy should be commensurate in matched metrical and mismatched metrical conditions (unless general metric preferences elevate performance in one of these conditions).

In the *nonprioritised integrative attending condition*, listeners are required to attend to, and memorise, only the aggregate aspect of the multipart patterns. As with selective attending, it is expected that recognition accuracy for aggregate patterns will be generally better under nonprioritised integrative attending (i.e., single task) conditions than under prioritised integrative attending (i.e., dual task) conditions. This difference should be less marked for individuals who have acquired experience at prioritised integrative attending through musical ensemble performance. It should also be the case that the effects of multipart rhythmic complexity upon accuracy at recognising aggregate patterns are attenuated under nonprioritised, relative to prioritised, integrative attending conditions. Therefore, smaller differences (if any) in recognition accuracy are expected across matched metrical, mismatched metrical, and nonmetrical conditions when integrative attending is nonprioritised than when it is prioritised. In other words, the complexity of the relationship between target integrant and aggregate patterns should be less influential when the task does not require attention to be focused simultaneously on both multipart pattern aspects. Effects of the location of temporal deviations in distracter memory test items will also be examined in order to allow a finer grained analysis of the timecourse of attending to multipart patterns.

## 6.2.2 Method

### 6.2.2.1 Participants

Seventy-two musicians (40 females and 32 males) and 72 nonmusicians (44 females and 28 males) volunteered to participate in Multipart Experiment 1 (N = 144). Median age was 23.75 years for musicians and 21.5 years for nonmusicians. Musicians had, on average, approximately 13.85 years experience playing an instrument. Some nonmusicians had played an instrument in the past (4.46 years experience),[19] but were no longer playing

[19] The criterion of maximum three years instrumental experience for nonmusicians (see 4.4.2) was relaxed for the multipart experiments due to the complexity of the task.

regularly. All musicians performed in ensembles regularly (with an average ensemble experience of 9.57 years). Some nonmusicians had performed in ensembles (average experience of 2.31 years), but none had done so regularly in at least three years prior to the experiment.

#### 6.2.2.2 Design

A 2 x 3 x 3 x (3 x 4) factorial design was employed. The between groups factors were *musicality* (musician; nonmusician), *attending mode* (prioritised integrative attending; selective attending; nonprioritised integrative attending), and *rhythm set subgroup* (subgroup-a; subgroup-b; subgroup-c). The within group factors were *multipart rhythmic complexity* (matched metrical; mismatched metrical; nonmetrical) and *test item type* (target; distracter-x; distracter-y; distracter-z). The three multipart rhythmic complexity conditions are distinguishable on the basis of the relationship between the target integrant and the aggregate patterns they contain: *matched metrical* – quadruple target integrant / quadruple aggregate; *mismatched metrical* – triple target integrant / quadruple aggregate; *nonmetrical* – nonmetrical target integrant / quadruple aggregate.

The subgroup factor was included so that multipart rhythmic complexity could be treated as a within groups variable without individual participants encountering the aggregate pattern from any given rhythm set in more than one experimental block. Therefore, each subgroup accounted for the three levels of complexity with different combinations of target integrant (quadruple, triple, or nonmetrical) and aggregate patterns, with the constraint that all integrant/aggregate combinations were exhausted across subgroups (see Appendix 6.1). Musicians and nonmusicians were allocated randomly into the nine subgroup x attending mode conditions.

#### 6.2.2.3 Stimuli and Apparatus

Multipart patterns were employed as ‘exposure items’ in the matched metrical, mismatched metrical and nonmetrical attending mode conditions. However, different types of pattern were used as ‘memory test items’ in each condition. Both singlepart integrant and singlepart aggregate patterns were used as memory test items in the prioritised integrative attending condition, but only singlepart integrant patterns were used in the selective attending condition, and only singlepart aggregate patterns were used in the nonprioritised integrative attending condition. The patterns serving as exposure items and memory test items were taken from the 12 best rhythm sets identified in Singlepart Experiment 1 (see 4.4.4.1 for a full description of the rhythm sets).

The multipart patterns used as exposure items are composed of a target and a complementary integrant pattern. One target integrant pattern in each rhythm set best fits a quadruple meter, one best fits a triple meter, and one is nonmetrical. Within any given rhythm set, these three target integrant patterns combine with their associated complementary patterns to form the same quadruple aggregate pattern. Thus, the three multipart rhythmic complexity conditions – matched metrical, mismatched metrical, nonmetrical – were accounted for. Thirty-six multipart patterns were used in total – three from each of 12 rhythm sets. In all the multipart stimulus patterns, the target integrant pattern was articulated by a conga drum sound and the complementary integrant pattern was articulated by a cow bell sound.

Integrant memory test items consisted of target and distracter integrant patterns. Each of the three (one quadruple, one triple, and one nonmetrical) target integrant patterns within a rhythm set has three related distracter patterns (d-$x_i$, d-$y_i$, d-$z_i$). Therefore, a total of 36 target and 108 distracter integrant patterns was used – three target and nine distracter integrant patterns from each rhythm set. Integrant memory test items were articulated by a conga drum sound.

Aggregate memory test items consisted of target and distracter (singlepart) aggregate patterns. Twelve quadruple target, and 36 quadruple distracter aggregate patterns were used – there is one target, and three associated distracter aggregate patterns (d-$x_a$, d-$y_a$, d-$z_a$), in each rhythm set. Aggregate memory test items were articulated by a snare drum sound.

A MIDI velocity value of 96 was assigned to all sounds. Participants were given the opportunity to adjust the loudness level if it was not comfortable, but none of them chose to do so.

Apparatus included AKG headphones and MAX software running on a Macintosh computer, as described in section 4.4.3.

#### 6.2.2.4 Procedure

Participants were tested individually at the computer in a small sound attenuated room. Before commencing the test session, the participant completed a training session consisting of (a) a computer-based tutorial aimed at establishing that the participant could detect the types of changes that distinguished target and distracter patterns (see Appendix 6.2), and (b) an exercise that provided detailed instructions (see Appendix 6.3) and an opportunity to practice the task in one experimental block. The training session was followed by a test session consisting of six blocks – two for each multipart rhythmic complexity condition (matched metrical; mismatched metrical; nonmetrical). Block order was randomised. Pattern presentation rate was varied between blocks according to specifications in section 4.4.4.3.1. When the six experimental blocks were completed, the participant was given a brief questionnaire on which they rated (a) how demanding they found the task on a 7-point scale, and (b) how often they felt that they were guessing on a 5-point scale (see Appendix 6.4).

The task in each experimental block basically involved exposure to a multipart pattern, followed by a recognition memory test for either the target integrant, or the aggregate aspect of the multipart exposure item. However, participants in each attending mode condition received different instructions regarding the aspect/s (integrant and/or aggregate) of the multipart exposure item to which they should attend. Participants in the prioritised integrative attending condition were asked to attend to both the target integrant and aggregate patterns, whereas participants in the selective and nonprioritised integrative attending conditions were instructed to attend to only the target integrant pattern, or the aggregate pattern, respectively. Attending mode conditions also differed in terms of the type of stimulus pattern used as test items. In the prioritised integrative attending condition, test items were target and distracter integrant and aggregate patterns. In the selective attending condition, only target and distracter integrant patterns served as test items, and in the nonprioritised integrative attending condition, only target and distracter aggregate patterns were used as test items. More detailed descriptions of the attending mode conditions are given below.

#### *6.2.2.4.1 Prioritised integrative attending condition*

Each of the six experimental blocks in the prioritised integrative attending condition contained 10 trials. Each trial consisted of a multipart exposure item followed by a memory test item. The multipart exposure item was the same in each of the 10 trials within a block. The memory test item following each exposure item was either a target, distracter-$x_i$, distracter-$y_i$, or distracter-$z_i$ singlepart integrant pattern, or a target, distracter-$x_a$, distracter-$y_a$, or distracter-$z_a$ singlepart aggregate pattern. The first four trials of every block contained a target integrant, a distracter-$z_i$ integrant, a target aggregate, and a distracter-$z_a$ aggregate memory test item (presented in random order for each participant). Each of the remaining six trials within a block contained either a target, a distracter-$x_i$, or a distracter-$y_i$ integrant test item, or a target, a distracter-$x_a$, or a distracter-$y_a$ aggregate test item (in random order). A diagrammatic representation of one complete block in the prioritised integrative attending condition is given in Figure 6.3.

The participant was instructed to listen to each exposure item, and simultaneously to memorise the integrant, or ‘part’, pattern (played by the conga drum), and the aggregate, or ‘whole’, pattern that resulted from combining the target (conga drum) and complementary (cow bell) integrant patterns. One second after the exposure item ended, either the words ‘PART TEST’ or ‘WHOLE TEST’ appeared on the computer screen. When the ‘PART TEST’ message appeared, a target or distracter integrant test item was presented 3 s later. When the ‘WHOLE TEST’ message appeared, a target or distracter aggregate test pattern was presented after a 3 s silent interval. The participant was required to rate (on a 6-point scale identical to the one used in Singlepart Experiment 2) the degree to which they were confident that the integrant or aggregate test item was the same as, or different to, the target integrant or aggregate pattern, respectively. Information about whether memory would be tested for the target integrant or aggregate pattern was withheld until after the exposure item had been presented in order to encourage the participant to attend simultaneously to both integrant and aggregate aspects of the multipart pattern.

The prioritised integrative attending condition took approximately 1 hour to complete.

| | |
|---|---|
| **EXPOSURE** | EXPOSURE 1 |
| Target integrant | `x-----------x---x--------------xx-------x---x-x-x` |
| Complementary integrant | `------o-o-o---o------ooooooo-oo-----o--o---------` |
| **MEMORY TEST** | WHOLE TEST |
| Target aggregate | `v-----v-v-v-v-v-v----vvvvvvv-vvvv---v--vv---v-v-v` |
| **EXPOSURE** | EXPOSURE 2 |
| Target integrant | `x-----------x---x--------------xx-------x---x-x-x` |
| Complementary integrant | `------o-o-o---o------ooooooo-oo-----o--o---------` |
| **MEMORY TEST** | PART TEST |
| Target integrant | `x-----------x---x--------------xx-------x---x-x-x` |
| **EXPOSURE** | EXPOSURE 3 |
| Target integrant | `x-----------x---x--------------xx-------x---x-x-x` |
| Complementary integrant | `------o-o-o---o------ooooooo-oo-----o--o---------` |
| **MEMORY TEST** | WHOLE TEST |
| Distracter-z aggregate | `v---v--vv---v-v-v----vvvvvvv-vvvv-----v-v-v-v-v-v` |
| **EXPOSURE** | EXPOSURE 4 |
| Target integrant | `x-----------x---x--------------xx-------x---x-x-x` |
| Complementary integrant | `------o-o-o---o------ooooooo-oo-----o--o---------` |
| **MEMORY TEST** | PART TEST |
| Distracter-z integrant | `x---------x---x--------------xx---------x---x-x-x` |
| **EXPOSURE** | EXPOSURE 5 |
| Target integrant | `x-----------x---x--------------xx-------x---x-x-x` |
| Complementary integrant | `------o-o-o---o------ooooooo-oo-----o--o---------` |
| **MEMORY TEST** | WHOLE TEST |
| Target aggregate | `v-----v-v-v-v-v-v----vvvvvvv-vvvv---v--vv---v-v-v` |
| **EXPOSURE** | EXPOSURE 6 |
| Target integrant | `x-----------x---x--------------xx-------x---x-x-x` |
| Complementary integrant | `------o-o-o---o------ooooooo-oo-----o--o---------` |
| **MEMORY TEST** | PART TEST |
| Target integrant | `x-----------x---x--------------xx-------x---x-x-x` |
| **EXPOSURE** | EXPOSURE 7 |
| Target integrant | `x-----------x---x--------------xx-------x---x-x-x` |
| Complementary integrant | `------o-o-o---o------ooooooo-oo-----o--o---------` |
| **MEMORY TEST** | WHOLE TEST |
| Distracter-x aggregate | `v-----v-v-v-v-v-v---v--vv---v-v-v----vvvvvvv-vvvv` |
| **EXPOSURE** | EXPOSURE 8 |
| Target integrant | `x-----------x---x--------------xx-------x---x-x-x` |
| Complementary integrant | `------o-o-o---o------ooooooo-oo-----o--o---------` |
| **MEMORY TEST** | PART TEST |
| Distracter-x integrant | `x-----------x---x------------xx---------x---x-x-x` |
| **EXPOSURE** | EXPOSURE 9 |
| Target integrant | `x-----------x---x--------------xx-------x---x-x-x` |
| Complementary integrant | `------o-o-o---o------ooooooo-oo-----o--o---------` |
| **MEMORY TEST** | WHOLE TEST |
| Distracter-y aggregate | `v----vvvvvvv-vvvv-----v-v-v-v-v-v---v--vv---v-v-v` |
| **EXPOSURE** | EXPOSURE 10 |
| Target integrant | `x-----------x---x--------------xx-------x---x-x-x` |
| Complementary integrant | `------o-o-o---o------ooooooo-oo-----o--o---------` |
| **MEMORY TEST** | PART TEST |
| Distracter-y integrant | `x---------x---x----------------xx-------x---x-x-x` |

**Figure 6.3:** Example experimental block from the prioritised integrative attending condition of Multipart Experiment 1.

#### *6.2.2.4.2 Selective attending condition*

The task in the selective attending condition was essentially the same as the task in the prioritised integrative attending condition, with the exception that trials containing aggregate test items were omitted. Therefore, there were only five trials in each of the six experimental blocks (two blocks per multipart rhythmic complexity condition). Each of the five trials within a block consisted of the same multipart exposure item, followed by an integrant pattern test item (see unfilled panels of Figure 6.3). The participant was instructed to attend to, and memorise, only the target integrant pattern. They were told that the complementary integrant patterns served as interfering stimuli that should be ignored. As in the prioritised integrative attending condition, the words 'PART TEST' appeared on the computer screen 1 s after the exposure item had ended, and then the test item followed after a further 3 s had elapsed. The test items in the first two trials of each block were a target integrant, and a distracter-$z_i$ integrant pattern (presented in random order). The remaining three trials in each block featured either a target, a distracter-$x_i$, and a distracter-$y_i$ integrant pattern (in random order). Participants were required to rate the degree to which they were confident that the test item was the same as, or different to, the target integrant aspect of the exposure item.

The selective attending condition took approximately 40 mins to complete.

#### *6.2.2.4.3 Nonprioritised integrative attending condition*

The task in the nonprioritised integrative attending condition was the same as the task in the prioritised integrative attending condition, except that trials containing integrant test items were omitted. Therefore, there were five trials within each of the six blocks, and these trials consisted of the same multipart exposure item, followed an aggregate pattern test item (see shaded panels of Figure 6.3). The participant was instructed to attend to, and memorise, the aggregate pattern. As in the prioritised integrative attending condition, the words 'WHOLE TEST' appeared on the computer screen 1 s after the exposure item had ended, and then the test item followed 3 s later. The test items in the first two trials of each block were a target aggregate, and a distracter-$z_a$ aggregate pattern (presented in random order). The remaining three trials in each block contained either a target, a distracter-$x_a$, and a distracter-$y_a$ aggregate pattern (in random order). Participants were required to rate the degree to which they were confident that the test item was the same as, or different to, the aggregate aspect of the exposure item.

The nonprioritised integrative attending condition took approximately 40 mins to complete.

#### 6.2.2.5 Analyses

Two separate 2 x 3 x 2 x (3 x 3) ANOVAs – with variables musicality x subgroup x attending mode x (multipart rhythmic complexity x test item type) – were conducted upon participants' ratings of test items. Orthogonal planned contrasts were used in all analyses. In one analysis, ratings for integrant pattern test items in the prioritised integrative attending condition were compared with ratings in the selective attending condition (see Appendix 6.5). In the other analysis, ratings for aggregate pattern test items in the prioritised integrative attending condition were compared with ratings in the nonprioritised integrative attending condition (see Appendix 6.6). Therefore, only two levels of the attending mode variable were included in each analysis. Furthermore, only ratings produced in response to the final six trials of each experimental block in the prioritised integrative attending condition, and the final four trials of blocks in the selective and nonprioritised integrative attending conditions, were considered in the analyses. These trials were comprised of target, distracter-x, and distracter-y integrant and aggregate patterns. Responses to earlier trials were excluded on the basis that they may be less reliable than later responses due to relative lack of familiarity with exposure items at this stage of the block. Dropping distracter-z patterns had the effect of eliminating one value from *test pattern type* factor. As in Singlepart Experiment 2, supplementary item ANOVAs were carried out to ascertain how well effects generalise across different exemplars of rhythm patterns (see Appendices 6.7 & 6.8). The results of the conventional (i.e., participants as the random variable) and item analyses are reported separately only when they disagree about whether an effect is statistically significant. Otherwise, only F-values obtained from the conventional analysis are cited.

In these ANOVAs, alpha was set at .05. In the conventional analyses, the critical value for $F(1,84)$ is 3.96. In the item analysis, the critical value for $F(1,36)$ is 4.11.

Responses to the post-test questionnaire were analysed using separate 2 x 3 x 3 (musicality x subgroup x attending mode) ANOVAs for 'demandingness' and 'guessing' ratings. For these analyses, alpha was also set at .05 and the critical value for $F(1,126)$ is 3.92.

## 6.2.3 Results

### 6.2.3.1 Target integrant recognition accuracy

Same/different confidence ratings for target and distracter integrant test items in prioritised integrative attending and selective attending conditions are shown in Figure 6.4. The analysis revealed that target integrant items received significantly higher ratings than distracter integrant items, $F(1,84) = 23.99$. Furthermore, ratings were significantly lower for distracter-$y_i$ than distracter-$x_i$ items, $F(1,84) = 6.14$. These results indicate that although listeners were able to differentiate reliably between target and distracter items in general, they were more sensitive to deviations in distracter-$y_i$ (where deviations occurred early in the pattern) than distracter-$x_i$ items (late deviations). The effect of distracter type was more pronounced in the metrical, than in the nonmetrical condition, $F(1,84) = 5.7$. However, there was no significant difference in accuracy due to musicality, $F(1,84) = 1.01$. Musicians and nonmusicians were equally good at recognising target integrant patterns. Furthermore, there were no significant differences in accuracy due to attending mode. Perhaps the difference in the number of times multipart exposure patterns were presented across initial ‘familiarisation’ trials in prioritised integrative attending (four presentations) and selective attending (two presentations) conditions contributed to this lack of effect: the greater number of presentations may have compensated for the relative difficulty of prioritised integrative attending. This possibility shall be pursued in the discussion.

Surprisingly, contrary to predictions, there was no evidence that multipart rhythmic complexity affected the recognition of target integrant patterns. Accuracy was no greater in metrical conditions than in nonmetrical conditions, $F(1,84) = 3.74$. There was also no difference between accuracy in matched and mismatched metrical conditions $F(1,84) = 2.59$. Likewise contrary to predictions, complexity did not produce effects through interactions with attending mode or musicality.

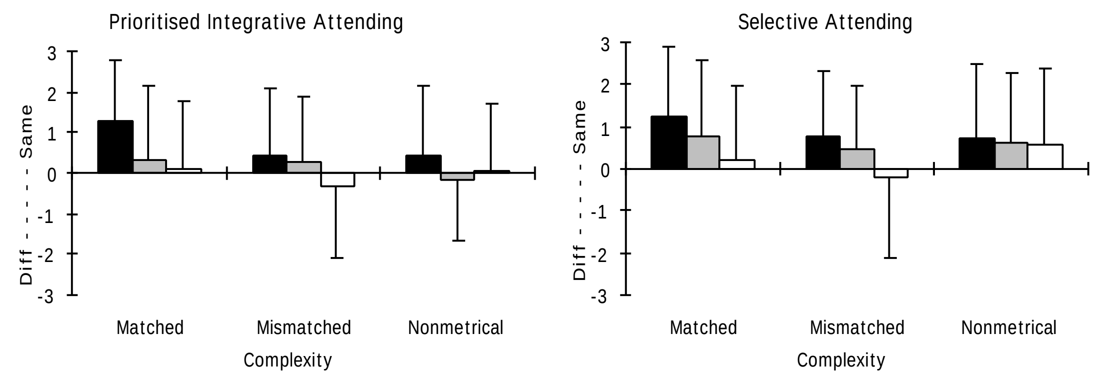


**Figure 6.4:** Recognition accuracy for integrant patterns in prioritised integrative attending and selective attending conditions. Average same/different confidence ratings are shown for target (filled black), distracter-$x_i$ (filled grey), and distracter-$y_i$ (unfilled) items in matched metrical, mismatched metrical, and nonmetrical multipart rhythmic complexity conditions.

#### 6.2.3.2 Aggregate recognition accuracy

Same/different confidence ratings for target and distracter aggregate test items in prioritised and nonprioritised integrative attending conditions are shown in Figure 6.5. The analysis revealed that target aggregate items received significantly higher ratings than distracter aggregate items, $F(1,84) = 185.8$. This difference was affected by musicality, $F(1,84) = 10.8$. As predicted, musicians displayed greater recognition accuracy than nonmusicians: mean difference between ratings for target and distracter patterns was 2.21 ($SD = 1.45$) for musicians, but only 1.35 ($SD = 1.43$) for nonmusicians.

There was also a significant difference between ratings of distracter-$x_a$ and distracter-$y_a$ patterns, $F(1,84) = 43.56$. Ratings were lower for distracter-$x_a$ than distracter-$y_a$ items, indicating that listeners were better at detecting structural changes when they occurred late in the pattern, than when they occurred early.[20] This effect was more pronounced in metrical than in nonmetrical conditions, but only according to the item analysis, $F(1,36) = 4.42$. Furthermore, the effect of distracter type was larger in the prioritised, than in the nonprioritised, integrative attending condition, $F(1,84) = 6.1$.

[20] Note that in distracter *aggregate* patterns, d-$y_a$ changes occur in the final portion of patterns, but in distracter *integrant* patterns, d-$y_i$ changes occur in the initial portion.

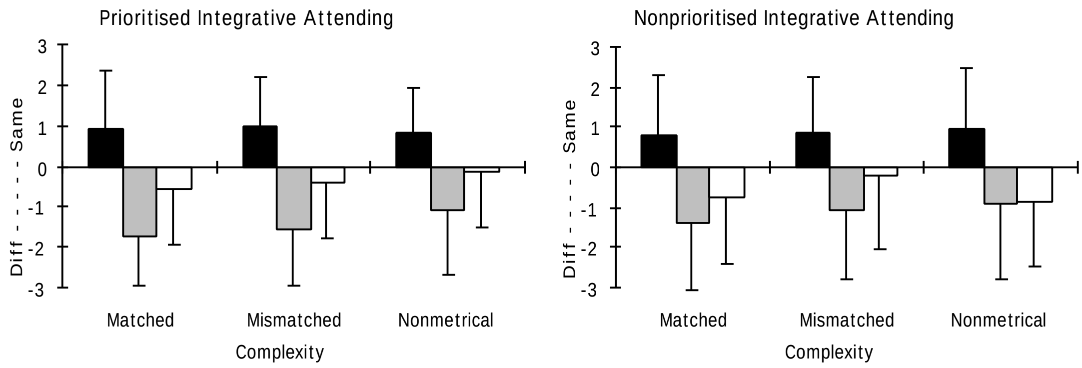


**Figure 6.5:** Recognition accuracy for aggregate patterns in prioritised integrative attending and selective attending conditions. Average same/different confidence ratings are shown for target (filled black), distracter-$x_a$ (filled grey), and distracter-$y_a$ (unfilled) items in matched metrical, mismatched metrical, and nonmetrical multipart rhythmic complexity conditions.

Most notably, consistent with predictions, ability to differentiate between target and distracter patterns was affected significantly by the interaction of multipart rhythmic complexity and attending mode, $F(1,84) = 5.66$.[21] Recognition accuracy was greater in metrical conditions than in nonmetrical conditions when integrative attending was prioritised, but not when it was nonprioritised. Musicality did not interact significantly with either complexity or attending mode.

#### 6.2.3.3 Subjective indices of task difficulty

Musicians' and nonmusicians' ratings of how demanding they found the task, and the degree to which they felt they were guessing during memory tests, are shown in Figures 6.6 and 6.7, respectively. Separate 2 x 3 x 3 (musicality x subgroup x attending mode) ANOVAs carried out on 'demandingness' and 'guessing' ratings did not reveal any significant differences between the three attending mode conditions (see Appendices 6.9 & 6.10, respectively). Therefore, participants experienced equivalent levels of difficulty across conditions.

[21] This effect was not significant according to the item analysis, $F(1,36) = 3.52$.

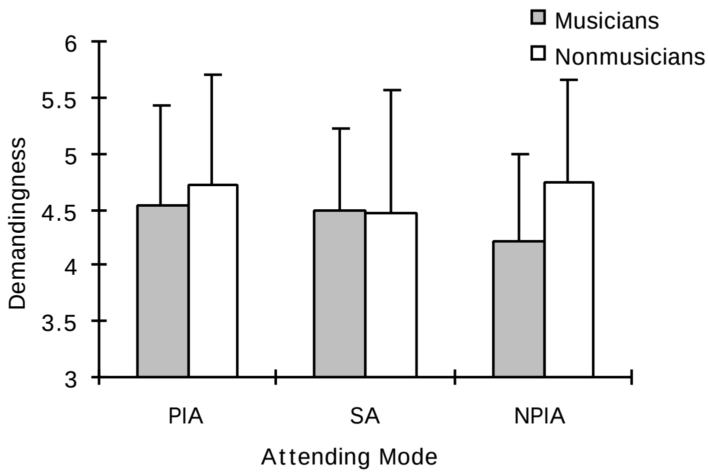


**Figure 6.6:** Average 'demandingness' ratings (on a 7-point scale) produced by musicians and nonmusicians in the prioritised integrative attending (PIA), selective attending (SA), and nonprioritised integrative attending (NPIA) conditions.

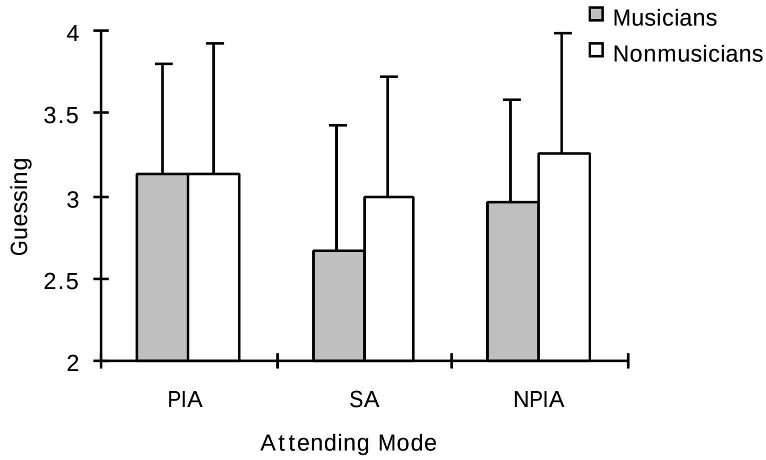


**Figure 6.7:** Average 'guessing' ratings (on a 5-point scale) produced by musicians and nonmusicians in the three attending mode conditions.

### 6.2.4 Discussion

The hypothesis that prioritised integrative attending proceeds more efficiently at low, than at high levels of multipart rhythmic complexity was supported by findings relating to accuracy of aggregate pattern recognition. Following simultaneous encoding of target integrant and aggregate aspects of multipart patterns, recognition accuracy for aggregate patterns was superior when target integrant patterns were metrical than when they were nonmetrical. This indicates that the process of attending to aggregate pattern structure is interfered with to a greater degree by nonmetrical target integrant patterns than by metrical integrant patterns. Thus, attentional flexibility is enhanced when listeners have the opportunity to use metric frameworks associated with target integrant patterns. The lack of effect of multipart rhythmic complexity upon aggregate pattern recognition under nonprioritised integrative attending conditions demonstrates that efficiency of aggregate pattern encoding is a function of the interaction of multipart structure and attending mode, rather than multipart structure alone. This suggests that the observed differences in aggregate pattern recognition are peculiar to prioritised integrative attending, and not merely an artefact of the way in which target and complementary integrant patterns were arranged.

In light of these findings with aggregate patterns, it is interesting that there were no reliable effects of multipart rhythmic complexity upon the recognition of target integrant patterns. This finding is particularly surprising because reliable differences in recognition accuracy were observed in Singlepart Experiment 2 with patterns identical to the current target integrant patterns. There are several possible explanations for the present lack of effect. Perhaps difficulties associated with the prioritised integrative attending task jeopardised target integrant encoding across all levels of multipart complexity. This is unlikely given that null results occurred under both prioritised integrative and selective attending conditions (and also because subjective experiences of difficulty did not differ between the conditions). Alternatively, the mere presence of complementary integrant patterns may have interfered with target integrant encoding. Finally, target integrant recognition may have been compromised by contextual differences between exposure (where complementary patterns were present) and test (complementary patterns absent). These explanations, though more plausible than the first, are equally likely on the basis of present results. Further studies would be required to distinguish between them.

Another unexpected finding is commensurate target integrant recognition accuracy under prioritised integrative attending conditions (where attentional demands are high) and selective attending conditions (where demands are relatively low). As suggested in the results section, the lack of difference between performance in the two may stem from more exposure to target integrant patterns in experimental blocks requiring prioritised integrative attending, where there were twice as many familiarisation trials than in selective attending blocks. It was assumed that the difference in number of familiarisation trials is justified because attention is divided between target integrant and aggregate aspects of the exposure pattern in prioritised integrative attending trials, whereas full attention is directed to the target integrant in selective attending trials. Nevertheless, it may be the case that representations of target integrants are enhanced *merely* through more exposure under prioritised integrative attending conditions. Indeed, evidence is mounting in the implicit memory literature (specifically in investigations of *mere exposure effects*) that stable representations are formed for musical sequences even in the absence of deliberate attempts at memorisation (see Crowder, 1993a; Gaudreau & Peretz, 1999). Consistent with the 'lack of awareness' that characterises mere exposure effects, participants' subjective reports of demandingness and guesswork indictated that similar levels of task difficutly were experienced in each attending mode condition.

The finding that listeners were better at detecting deviations located early in integrant test items (a primacy effect) was unexpected, and is, in fact, the opposite to what was found in Singlepart Experiment 2 (a recency effect). Perhaps the current primacy effect occurred due to the influence of complementary pattern elements. Specifically, the amount of interference to target integrant pattern encoding produced by complementary elements (i.e., the individual events comprising the pattern) may accumulate as their number increases over the duration of an exposure item. Therefore, less interference is encountered at early locations, leading to the formation of more stable representations for the initial portions of target integrant patterns. This is consistent with the notion of ongoing perturbation to an attentional oscillator (see Large & Jones, 1999). It was also found that sensitivity to early deviations was more pronounced with metrical, than nonmetrical, integrant test items. Perhaps this is evidence that attentional oscillators were weaker, or not induced in nonmetrical conditions (where, it should be noted, the aggregate pattern was metrical). In any case, this finding is noteworthy in so far as it provides some evidence of differences in performance with integrant patterns based on metricality.

The finding that listeners displayed greater sensitivity to late, than early, structural changes in aggregate test items can be explained more convincingly than the unexpected findings discussed above. This recency effect may relate to the predictable manner in which multipart exposure items end. All exposure items were terminated by a group comprising two or three elements in the target integrant pattern. This predictability may have allowed listeners to devote a greater portion of attentional resources to the task of encoding aggregate pattern structure at the closing stage of each exposure item. The finding that the aggregate pattern recency effect was stronger when target integrant patterns were metrical than when they were nonmetrical adds weight to this claim, as predictability is greater in the former. Further support comes from the finding that larger recency effects occurred under prioritised integrative attending conditions, where attending to target integrant structure was a requirement, than under nonprioritised integrative attending conditions.

Musicality had mixed effects. Musicians and nonmusicians were equally accurate at recognising target integrant patterns, but musicians were advantaged when it came to recognising aggregate patterns. These findings suggest that, although musical experience has little effect upon ability to focus attention upon individual integrant patterns, it becomes more influential when the listener must attend to the relationship between target and complementary integrant patterns in order to derive aggregate pattern structure. In short, the benefits of musical experience emerge only when trans-integrant grouping becomes necessary. Furthermore, there was no evidence for musicality-based differences in sensitivity to the complexity of the relationship between integrant and aggregate aspects: the effects of multipart rhythmic complexity upon aggregate pattern recognition were commensurate in musicians and nonmusicians. Thus, musical skill enables generally greater attentional flexibility in multipart contexts, but, contrary to predictions, does not lead to enhanced flexibility at low levels of multipart rhythmic complexity.

## 6.3 Multipart Experiment 2: Efficiency at retrieval

### 6.3.1 Overview

Multipart Experiment 2 investigates the effects of retrieving previously memorised target integrant patterns upon the ability to memorise aggregate patterns. The process of retrieving an integrant pattern whilst attending to aggregate pattern structure presents demands that are routinely met in multipart listening and performance contexts (sees 3.4.3.1.2 and 3.4.3.1.3). For example, when listening to a new performance of a familiar piece of ensemble music, the listener may attempt to recall a particular part, as realised in a favourite past interpretation, in order to make comparisons with the current performance. Likewise, when engaged in ensemble performance, performance goals and plans stored in memory must be accessed to aid production of one's part. In both cases, it is usually beneficial for the attender to encode the whole ensemble texture whilst recalling their target part.

Retrieval under prioritised integrative attending conditions is examined in this experiment using a recognition memory paradigm consisting of three phases (see Figure 6.8). In the first phase, listeners are presented with an isolated target integrant pattern, which they are instructed to memorise. Then, in the second phase, memory for the target integrant pattern is tested by asking listeners to rate the similarity of target and distracter integrant test items that are embedded within the same aggregate pattern across several experimental trials. Listeners are also instructed to memorise the aggregate pattern whilst judging the similarity of integrant test items. Finally, in the third phase, memory is tested for the aggregate pattern.

Prioritised integrative attending is required in the second phase, during which listeners must simultaneously retrieve the target integrant pattern from memory (for comparison with integrant test items) and derive aggregate structure. It is assumed that the process of target integrant retrieval in this phase is guided by the proactive (i.e., top-down) generation of metric frameworks (at least when target integrant patterns are metrical). This style of generation, rather than reactive (i.e., bottom-up) generation during test item encoding, should be encouraged by the fact that distracter integrant test items incorporate changes that disrupt the metricality of their related target patterns (see 4.4.4.2.2).

As in Multipart Experiment 1, metricality is varied across target integrant patterns, but held constant for aggregate patterns, so as to produce three levels of multipart rhythmic complexity: matched metrical, mismatched metrical, and nonmetrical. Also in accordance to the previous experimental design, both selective attending and nonprioritised integrative attending conditions are included, in addition to the prioritised integrative attending condition (which is described in the preceding paragraph). In the selective attending condition, listeners are presented with only the first and second phases of the three phase procedure. As in the prioritised integrative attending condition, they memorise the target integrant pattern in the first phase, and then rate target and distracter integrant test items in the second phase. However, instead of being asked to memorise the aggregate pattern whilst making ratings, they are instructed to ignore the complementary integrant patterns that accompany test items. In the nonprioritised integrative attending condition, listeners receive only the second and third phases of the full procedure. They are asked to memorise the aggregate pattern and then rate target and distracter aggregate test items.

**(A) Target integrant exposure**

```
Exposure 1              x-------x---x----------xx-----------x-------x-x-x

Exposure 2              x-------x---x----------xx-----------x-------x-x-x

Exposure 3              x-------x---x----------xx-----------x-------x-x-x

Exposure 4              x-------x---x----------xx-----------x-------x-x-x
```

**(B) Integrant test / aggregate exposure**

```
Target integrant        x-------x---x----------xx-----------x-------x-x-x
Complementary integrant ------o---o---o-o----oo--ooo-oooo------oo--------

Distracter-x integrant  x-------x---x--------xx-------------x-------x-x-x
Complementary integrant ------o---o---o-o------ooooo-oooo------oo--------

Distracter-y integrant  x-----x---x------------xx-----------x-------x-x-x
Complementary integrant --------o---o-o-o----oo--ooo-oooo------oo--------

Distracter-z integrant  x-----x---x----------xx-------------x-------x-x-x
Complementary integrant --------o---o-o-o------ooooo-oooo------oo--------
```

**(c) Aggregate test**

```
Target aggregate        v-----v-v-v-v-v-v----vvvvvvv-vvvv---v--vv---v-v-v

Distracter-x aggregate  v-----v-v-v-v-v-v---v--vv---v-v-v----vvvvvvv-vvvv

Distracter-y aggregate  v----vvvvvvv-vvvv-----v-v-v-v-v-v---v--vv---v-v-v

Distracter-z aggregate  v---v--vv---v-v-v----vvvvvvv-vvvv-----v-v-v-v-v-v
```

**Figure 6.8:** Three phases of the experimental task in Multipart Experiment 2. Note that in Phase B the same aggregate structure is presented across all four trials even though the integrant patterns differ in each trial.

Following the assertion, made by Jones (1985) and other 'proceduralists' (Crowder, 1993a, 1993b), that encoding and retrieval are 'opposite sides of the same coin' (see 3.2.4), the hypotheses advanced here are the same as those in Multipart Experiment 1.

First, performance is expected to be better in metrical than nonmetrical conditions. Also, within metrical conditions, performance should be better when target integrant and aggregate patterns are matched in terms of meter, than when they are mismatched. Even though Multipart Experiment 1 failed to find differences between performance in matched and mismatched metrical conditions, such differences are expected here because the current task places more stringent constraints upon attending. The proactive style of metric framework generation that is assumed to underlie target integrant pattern retrieval may serve to strengthen commitment to a particular framework, and thereby amplify the effects of how well integrant and aggregate aspects of patterns are matched in terms of meter.

Second, with regard to the effects of attending mode, overall performance should be better in selective and nonprioritised integrative attending conditions than in prioritised integrative attending conditions. If the number of exposure items was responsible for the absence of such an effect in Multipart Experiment 1, then it should appear in the current experiment because the number of exposure items is identical across all attending mode conditions. Third, performance should be better by musicians than nonmusicians. Finally, several interactions are expected. The effects of multipart rhythmic complexity should be greater (a) in the prioritised integrative attending condition than in the selective and nonprioritised integrative attending conditions, and (b) in musicians than in nonmusicians. Furthermore, the effects of attending mode should be reduced in musicians relative to nonmusicians.

## 6.3.2 Method

### 6.3.2.1 Participants

Participants were the same 72 musicians and 72 nonmusicians (N = 144) who participated in Multipart Experiment 1. Half the participants did Multipart Experiment 2 before Multipart Experiment 1.

### 6.3.2.2 Design

The design was identical to that employed in Multipart Experiment 1. Between groups factors were *musicality* (musician; nonmusician), *attending mode* (prioritised integrative attending; selective attending; nonprioritised integrative attending), and *subgroup* (subgroup-a; subgroup-b; subgroup-c). Within group factors were *multipart rhythmic complexity* (matched metrical; mismatched metrical; nonmetrical) and *test item type* (target; distracter-x; distracter-y; distracter-z).

Participants were reallocated within subgroups (each of which accounted for the three levels of complexity with different tokens of patterns) as per the description in Appendix 6.1, so that they did not encounter the same stimulus items they received in Multipart

Experiment 1. Participants remained within the same attending mode condition across experiments.

#### 6.3.2.3 Stimuli and Apparatus

Stimuli were integrant and aggregate patterns from the same rhythm sets employed in Multipart Experiment 1. However, differences in experimental procedure necessitated some changes in the types of patterns used. Isolated target integrant patterns comprised the first type of pattern. These were either quadruple, triple, or nonmetrical, and were articulated by a conga drum sound. The second type of pattern comprised multipart patterns composed of target or distracter integrant patterns, and their complementary relatives. All three varieties of distracter integrant patterns were used: d-$x_i$, d-$y_i$, and d-$z_i$. Note that the same multipart aggregate pattern is obtained when the target, and each distracter integrant test item from a particular rhythm set is coupled with its related complementary pattern. Target and distracter integrant test items were articulated by a conga drum sound, and the complementary integrant patterns were articulated by a cowbell sound. The final type of stimulus pattern comprised target and distracter (d-$x_a$, d-$y_a$, d-$z_a$) aggregate patterns. These were used as aggregate test items, and were articulated by a snare drum sound. As all aggregate patterns are quadruple, the matched metrical condition contained quadruple target integrant patterns, the mismatched metrical condition contained triple target integrant patterns, and the nonmetrical condition contained nonmetrical target integrant patterns.

All sounds were assigned a MIDI velocity value of 96. Participants were given the opportunity to adjust the loudness level if it was not comfortable, but none of them chose to do so.

Apparatus consisted of the same headphones and computer as used in the previous experiments.

#### 6.3.2.4 Procedure

The current experimental procedure differed from the procedure in Multipart Experiment 1 only in terms of the experimental task. Participants were tested in the same environment as the previous experiment. As before, they completed a computer-based tutorial (see Appendix 6.2), and an exercise that provided detailed instructions (see Appendix 6.11) and were given an opportunity to practice the task in one experimental block. The training session was followed by a test session that featured six blocks – two blocks per experimental condition: matched metrical, mismatched metrical, and nonmetrical. Block order was randomised. Presentation rate was varied between blocks as in Multipart Experiment 1. At the completion of the test session, participants received the same questionnaire (which addresses perceived demandingness and subjective reports of guessing) used in the previous experiment. The current experimental task differed for participants in each attending mode condition: prioritised integrative attending, selective attending, and nonprioritised integrative attending, as described in the next three sub-sections.

#### *6.3.2.4.1 Prioritised integrative attending condition*

Each of the six experimental blocks (matched metrical, mismatched metrical, nonmetrical x 2 repetitions) in the prioritised integrative attending condition consisted of three phases: (a) integrant exposure; (b) integrant test / aggregate exposure; (c) aggregate test (see Figure 6.8). Each phase consisted of four trials (i.e., 12 trial per block) that were self-paced. The participant clicked with the computer mouse on a button on the computer screen to initiate each trial.

In the *integrant exposure phase*, participants received a single presentation of an isolated target integrant pattern (quadruple, triple, or nonmetrical, depending on experimental condition) on each trial. The participant was instructed to listen to the pattern, and to memorise it.

In the *integrant test / aggregate exposure phase*, the participant was tested for memory of the pattern presented during the integrant exposure phase, and simultaneously exposed to the target aggregate pattern. In each of four trials, two integrant patterns that were distinguishable on the basis of instrumental tone colour were presented concurrently. The integrant test item (played by the conga drum) was either the target integrant pattern or one of the three distracter integrant patterns (d-$x_i$, d-$y_i$, d-$z_i$), and the other integrant pattern (played by the cowbell) was the appropriate complementary integrant pattern. Combining integrant test items and their complementary patterns resulted in the *same* aggregate pattern. Thus, although the distribution of pattern elements between parts was different in each trial, the same aggregate pattern was exposed four times. Trial order was randomised in the integrant test / aggregate exposure phase. The participant was instructed to compare the test integrant pattern (conga drum) to the pattern they memorised during the integrant exposure phase, and, at the same time, to memorise the aggregate pattern that resulted from combining the test integrant item with the complementary integrant pattern (cowbell). At the conclusion of each trial, the participant was required to indicate (on the same 6-point scale used in previous experiments) the degree to which they were confident that the integrant test item was the same as, or different to, the pattern presented in the integrant exposure phase.

Finally, in the *aggregate test phase*, the participant was tested for memory of the aggregate pattern exposed in the integrant test / aggregate exposure phase. An aggregate test item (played by snare drum) was presented in each of the four trials comprising the aggregate test phase. Thus, the participant heard a target, and three distracter (d-$x_a$, d-$y_a$, d-$z_a$), aggregate test items across the four trials. Trial order was randomised. The participant was instructed to listen to each aggregate test item, and to indicate (on same scale used in the previous phase) the degree to which they were confident that it was the same as, or different to, the aggregate pattern exposed in the integrant test / aggregate exposure phase.

The prioritised integrative attending condition took approximately 1 hour to complete.

#### *6.3.2.4.2 Selective attending condition*

The task in the selective attending condition was the same as the task in the prioritised integrative attending condition, with the exception that the third phase – i.e., the aggregate test phase – was omitted. Consequently, the selective attending condition was comprised of six blocks (matched metrical, mismatched metrical, nonmetrical x 2 repetitions) with only two phases – an *integrant exposure phase* and an *integrant test phase* (see two upper panels of Figure 6.8). As in the prioritised integrative attending condition, each phase consisted of four trials (giving a total of eight trials per block). In the integrant test phase, the participant was told that the complementary integrant patterns served as interfering stimuli that should be ignored. Thus, they rated integrant test items, but were not required to memorise the aggregate pattern. The selective attending condition took approximately 40 mins to complete.

#### *6.3.2.4.3 Nonprioritised integrative attending condition*

The task in the nonprioritised integrative attending condition was the same as the task in the prioritised integrative attending condition, except that the first phase was omitted – i.e., there was no integrant exposure phase. Consequently, there were only two phases (each with four trials) in each of the six blocks – an *aggregate exposure phase* and an *aggregate test phase* (see two lower panels of Figure 6.8). In the aggregate exposure phase, the participant was instructed to memorise the aggregate pattern resulting from the combination of the two integrant patterns in each trial. Thus, both integrant patterns in each aggregate exposure item had equal status in the nonprioritised integrative attending condition. The nonprioritised integrative attending condition took approximately 40 mins to complete.

#### 6.3.2.5 Analyses

Two separate 2 x 3 x 2 x (3 x 4) ANOVAs – musicality x subgroup x attending mode x (multipart rhythmic complexity x test item type) – were carried out upon participants' ratings of test items. One analysis compared ratings for integrant test items in the prioritised integrative attending condition with ratings in the selective attending condition (see Appendix 6.12). In the other analysis, ratings for aggregate test items in the prioritised integrative attending condition were compared with ratings in the nonprioritised integrative attending condition (see Appendix 6.13). All comparisons were made using orthogonal planned contrasts.

As in previous experiments, supplementary item ANOVAs were also carried out (see Appendices 6.14 & 6.15). As in Multipart Experiment 1, the results of the conventional (i.e., participants as the random variable) and item analyses are reported separately only when they are in disagreement. Otherwise, F-values obtained from the conventional analysis are cited.

In all ANOVAs, alpha was set at .05. In the conventional analyses, the critical value for $F(1,84)$ is 3.96. In the item analysis, the critical value for $F(1,36)$ is 4.11.

As in Multipart Experiment 1, responses to the post-test questionnaire were analysed using separate 2 x 3 x 3 (musicality x subgroup x attending mode) ANOVAs for 'demandingness' and 'guessing' ratings. For these analyses, alpha was set at .05 and the critical value for $F(1,126)$ is 3.92.

## 6.3.3 Results

### 6.3.3.1 Target integrant recognition accuracy

Same/different confidence ratings for target and distracter integrant test items in prioritised integrative attending and selective attending conditions are shown in Figure 6.9. The conventional analysis revealed that target integrant items received significantly higher ratings than distracter integrant items, $F(1,84) = 93.75$, indicating that listeners were able to differentiate reliably between target and distracter items. Furthermore, there were significant effects of multipart rhythmic complexity, attending mode, and musicality. All of these effects were in accordance with predictions. Accuracy in recognising integrant patterns was greater in metrical conditions than in the nonmetrical condition, $F(1,84) = 4.89$. Performance was also generally better in the selective attending condition than in the prioritised integrative attending condition, $F(1,84) = 6.33$, and in musicians than in nonmusicians, $F(1,84) = 29.62$. There was also an interaction between complexity and musicality that conformed with predictions $F(1,84) = 8.64$. This interaction shows that the superiority of musicians over nonmusicians was stronger in metrical conditions than in nonmetrical conditions. The only result that conflicts with the predictions was the absence of a significant difference between performance accuracy in matched and mismatched metrical conditions.

One final effect to mention is that performance was better with distracter-$y_i$ (early deviation) test items than with distracter-$x_i$ test items (late deviation) in metrical conditions, but not in nonmetrical conditions, $F(1,84) = 5.53$. This effect was not significant according to the item analysis. It does, nevertheless, reinforce the corresponding effect in Multipart Experiment 1. There was also a significant three-way interaction between test item type (d-$x_i$ versus d-$y_i$), musicality, and attending mode, $F(1,84) = 5.53$. This interaction suggests that the general favouring of distracter-$y_i$ items was especially prevalent for musicians in the selective attending condition.

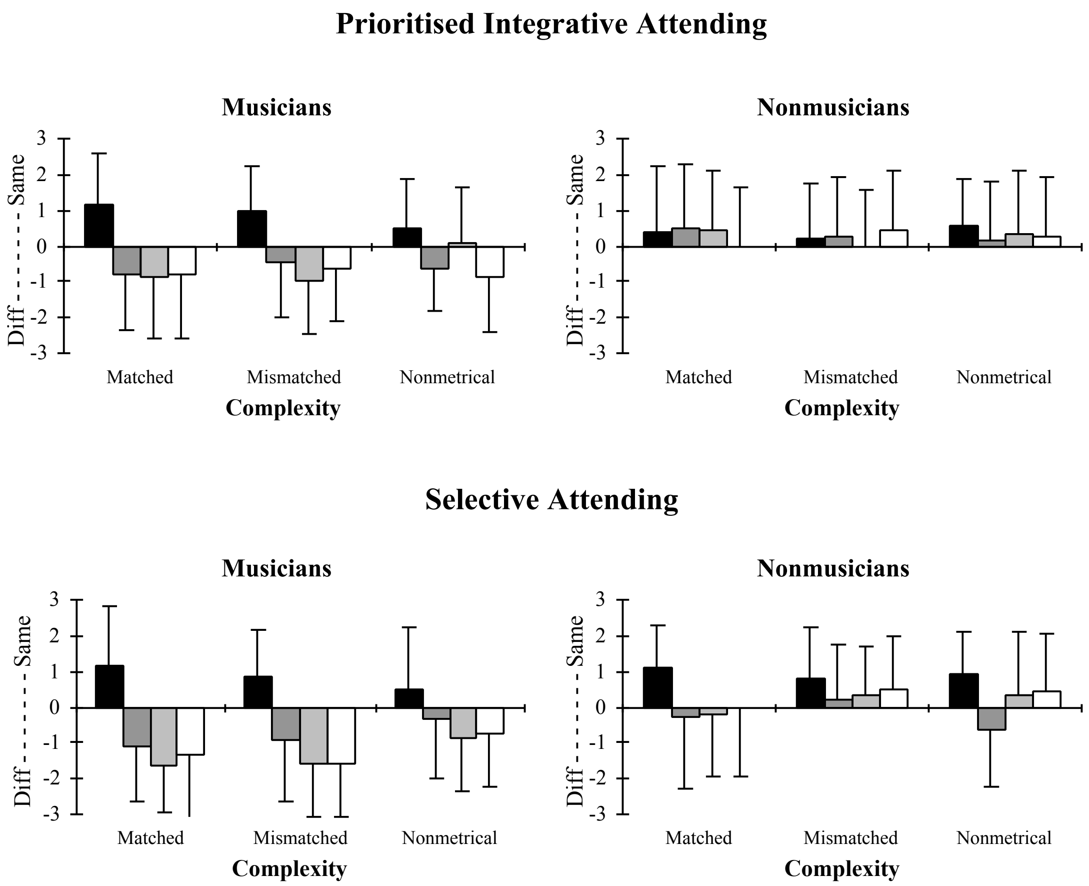


**Figure 6.9:** Recognition accuracy by musicians and nonmusicians for integrant patterns in prioritised integrative attending and selective attending conditions. Average same/different confidence ratings are shown for target (filled black), distracter-$x_i$ (dark grey), distracter-$y_i$ (light grey), and distracter-z (unfilled) items in matched metrical, mismatched metrical, and nonmetrical multipart rhythmic complexity conditions.

### 6.3.3.2 Aggregate recognition accuracy

Same/different confidence ratings for target and distracter aggregate test items in prioritised and nonprioritised integrative attending conditions are shown in Figure 6.10. It can be seen that target aggregate items received significantly higher ratings than distracter aggregate items, $F(1,84) = 172.07$, indicating that listeners were able to differentiate reliably between target and distracter items.

Overall accuracy at recognising aggregate patterns was affected by attending mode, $F(1,84) = 13.38$. In accordance with predictions, performance was better in the nonprioritised integrative attending condition than in the prioritised integrative attending condition. However, contrary to predictions, overall performance was not affected by musicality, $F(1,84) = 1.78$. Likewise, the main effect of multipart rhythmic complexity was not significant. However, a significant interaction between attending mode and complexity was detected by the item analysis $F(1,36) = 4.59$, (but was not significant according to the conventional analysis). This effect is striking because it is in the opposite direction to what was predicted, and what was found in Multipart Experiment 1. Performance was better in the *nonmetrical* condition than in metrical conditions with prioritised integrative attending, but this was not the case with nonprioritised integrative attending. Musicality did not enter into this interaction. Performance in the matched metrical condition did not differ significantly from performance in mismatched metrical condition, nor were there any statistically reliable interactions involving this variable.

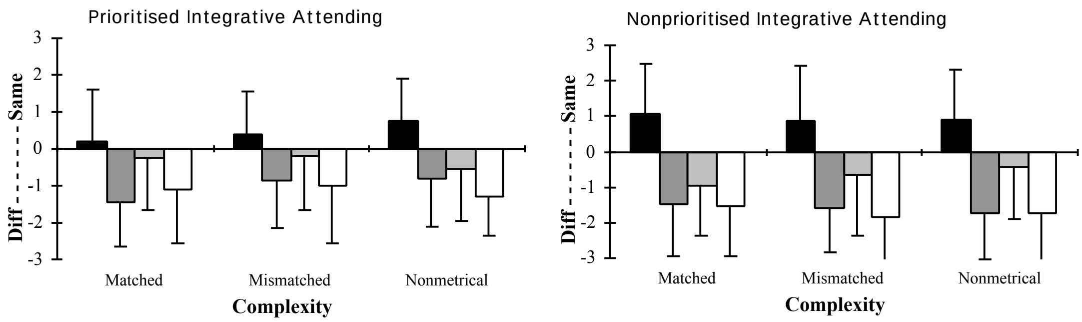


**Figure 6.10:** Recognition accuracy by musicians and nonmusicians for aggregate patterns in prioritised integrative attending and nonprioritised integrative attending conditions. Average same/different confidence ratings are shown for target (filled black), distracter-$x_a$ (dark grey), distracter-$y_a$ (light grey), and distracter-$z_a$ (unfilled) items in matched metrical, mismatched metrical, and nonmetrical multipart rhythmic complexity conditions.

Distracter item type also had significant effects. On the whole, listeners were more sensitive to changes in distracter-$z_a$ aggregate test items than in distracter-$x_a$ and distracter-$y_a$ items, $F(1,84) = 37.98$. Furthermore, sensitivity to changes was greater in distracter-$x_a$ items than in distracter-$y_a$ items, $F(1,84) = 37.55$. Thus, changes were most salient in distracter-$z_a$ items (changes at beginning and end), followed by distracter-$x_a$ items (changes at end), and finally distracter-$y_a$ items (changes at beginning). Complex interactions between distracter type, complexity, attending mode, and musicality also emerged (see Appendices 6.13 & 6.15). These were unexpected and are difficult to interpret.

### 6.3.3.3 Subjective indices of task difficulty

Musicians' and nonmusicians' ratings of how demanding they found the task, and the degree to which they felt they were guessing during memory tests, are shown in Figures 6.11 and 6.12, respectively. An ANOVA revealed a significant effect of attending mode upon demandingness ratings, $F(1,126) = 22.39$ (see Appendix 6.16). Participants reported that the prioritised integrative attending condition was more demanding than the selective attending and nonprioritised integrative attending conditions. A separate ANOVA for the guessing data revealed that guessing was affected reliably by both attending mode, F(1,126) = 9.2, and musicality, F(1,126) = 7.27 (see Appendix 6.17). As might be expected, guessing was more prevalent in the prioritised integrative attending condition than in the other two conditions combined, and in nonmusicians. There were no significant interactions between attending mode and musicality.

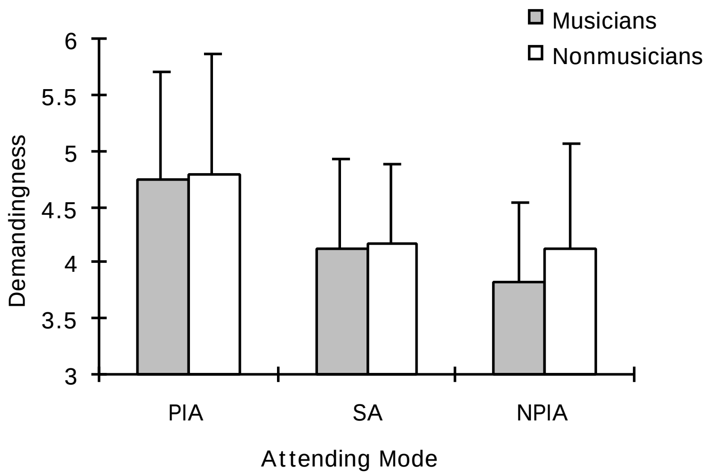


**Figure 6.11:** Average ‘demandingness’ ratings (on a 7-point scale) produced by musicians and nonmusicians in the prioritised integrative attending (PIA), selective attending (SA), and nonprioritised integrative attending (NPIA) conditions.

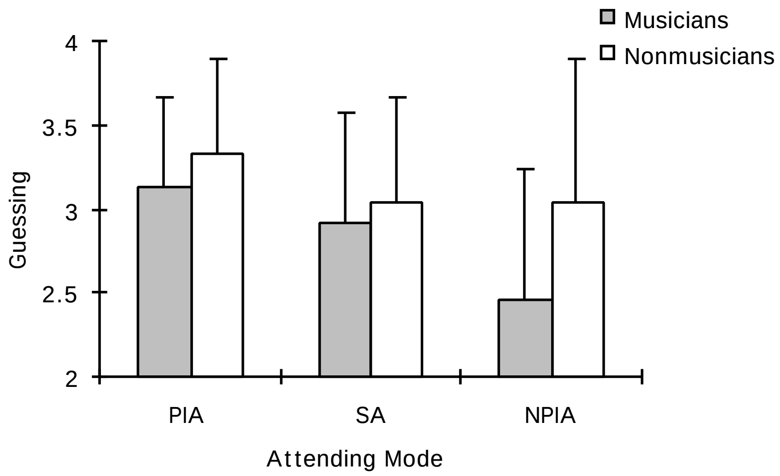


**Figure 6.12:** Average ‘guessing’ ratings (on a 5-point scale) produced by musicians and nonmusicians in the three attending mode conditions.

Two additional ANOVAs were conducted to examine differences in subjective reports of difficulty between Multipart Experiments 1 and 2 (see Appendix 6.18). The analysis of demandingness ratings revealed that Multipart Experiment 1 was considered more demanding than multipart experiment 2, $F(1,126) = 5.44$. In other words, the encoding task was felt to be more difficult than the retrieval task. There was also a significant effect of attending mode, $F(1,126) = 13.61$, indicating the prioritised integrative attending condition was considered most demanding. Furthermore, the interaction of these two was significant, $F(1,126) = 7.29$. The heightened demands associated with prioritised integrative attending were amplified in Multipart Experiment 2, relative to Multipart Experiment 1.

With regard to guesswork, guessing ratings were highest across both experiments in the prioritised integrative attending condition, $F(1,126) = 7.93$, and in nonmusicians, $F(1,126) = 8.69$. There was also a significant interaction between musicality and experiment, $F(1,126) = 6.61$: the tendency for nonmusicians to use guesswork was greater in Multipart Experiment 2 than in Multipart Experiment 1. It is tempting to suggest that this is why Multipart Experiment 2 was considered less demanding: guessing requires little effort.

### 6.3.4 Discussion

The results of the present experiment, which measured processing efficiency at retrieval, were markedly different from those of Multipart Experiment 1, in which efficiency at encoding was measured. In the earlier experiment, recognition of target integrant patterns was not affected by multipart rhythmic complexity, attending mode, or musicality, whereas in the current experiment reliable effects of all these variables were found.

In accordance with predictions about complexity, metrical target integrant patterns were recognised more accurately than nonmetrical target integrant patterns. Consistent with predictions about attending mode, accuracy at recognising integrant patterns was greater under selective attending conditions than when prioritised integrative attending was required. This suggests that constraints upon attentional flexibility are greater under prioritised integrative attending conditions (which present dual task demands) than under selective attending conditions (single task demands). Participants' subjective reports of demandingness support this claim. In accordance with predictions about musicality, not only were musicians generally more accurate than nonmusicians at recognising target integrant patterns, but their performance was disproportionately superior when the patterns were metrical. In other words, consistent with the results of Singlepart Experiment 2 (Metrical context effects), musical skill engenders greater sensitivity to metrical structure. There was also an overall tendency for musicians to engage in less guesswork, as indicated by their subjective reports. These findings suggest that attentional flexibility is enhanced by low complexity, low attentional demands, and high musical skill.

The effects of multipart rhythmic complexity upon integrant pattern recognition found in the present experiment stand in contrast to the absence of such effects in Multipart Experiment 1. It was argued there that this absence may be due to (a) distraction from complementary integrant patterns present during target integrant exposure, or (b) contextual differences between exposure and test phases. The findings of the current experiment support the former explanation, as exposure and test context differed in similar ways in both experiments, but the stage at which complementary integrant patterns were present varied. In Multipart Experiment 1, target integrant patterns were accompanied by complementary integrant patterns during exposure, but then memory was tested by presenting integrant test items in isolation. However, the opposite was the case in the current experiment: target integrant patterns were exposed in isolation, but then memory was tested in the presence of complementary integrant patterns. Despite these differences, primacy effects in integrant pattern recognition were observed in both experiments, which may indicate difficulty in maintaining attention to high priority integrant patterns in the presence of their complementary relatives. This indicates that these effects are robust as they appear to be independent of attentional demands during encoding and retrieval. The recency effect observed in both experiments with aggregate patterns are similarly robust.

The present findings also differed from those of Multipart Experiment 1 in that, currently, accuracy at recognising aggregate patterns was greater under nonprioritised integrative attending conditions than under prioritised integrative attending conditions, whereas no statistically reliable effect occurred in the previous experiment. Thus, as with integrant patterns, the predicted effects of attending mode on aggregates were realised only in the present experiment, where findings suggest that integrative attending places greater constraints on flexibility when it is prioritised than when it is nonprioritised. Once again, this was supported by subjective reports of demandingness.

Findings become perplexing when the effects of complexity and musicality upon performance with aggregate patterns are considered. The most surprising finding to emerge from the current experiment relates to the effects of multipart rhythmic complexity upon attending to aggregate pattern structure under prioritised integrative attending conditions. Contrary to predictions, aggregate patterns were recognised better when target integrant patterns being retrieved during their exposure were *nonmetrical* than when they were metrical. This effect did not occur under nonprioritised integrative attending conditions, and therefore it is unlikely that it was due to structural differences arising from the way in which pattern elements were distributed between target and complementary parts.

This startling finding is interesting because, although it is in direct opposition to the results of Multipart Experiment 1, overall recognition accuracy for aggregate patterns was similar in both experiments: on the whole, encoding- and retrieval-based tasks presented objectively equivalent levels of difficulty. However, the way in which multipart rhythmic complexity affects difficulty under these conditions appears to be very different. At face value, the current finding implies that attentional flexibility is restricted by proactive metric framework generation during the retrieval of metrical integrant patterns: an effect opposite to that observed with reactive metric framework generation during encoding in Multipart Experiment 1. However, there is a viable alternative explanation that is, in hindsight, consistent with the dynamic attending notion of expectancy violation. It may be the case that the 'qualitative' nature of the changes introduced to metrical target integrant patterns in order to convert them into distracter memory test items (causing them to become nonmetrical), produced expectancy violations that were sufficient to perturb the process of metric framework generation. This perturbation may have interfered with the processing of aggregate pattern structure (during the integrant test / aggregate exposure phase in the prioritised integrative attending condition). On the other hand, the more 'quantitative' changes associated with alterations to target nonmetrical patterns (the patterns remained nonmetrical) may not have been as disruptive, therefore allowing the aggregate pattern's best fitting metric framework to be generated reactively, and used to assist processing.

Findings within matched and mismatched metrical conditions also stand in opposition to predictions. As in Multipart Experiment 1, performance was not affected whether integrant and aggregate aspects of multipart patterns were matched or mismatched in terms of their best fitting meter. This finding is particularly surprising because the matched versus mismatched manipulation was expected to produce stronger effects in the current retrieval-based task due to the presumed unyielding nature of proactive (i.e., top-down) metric framework generation. Perhaps the lack of effect indicates a general insensitivity on the part of recognition memory paradigms. The current failure to find effects of musicality at the aggregate level is consistent with such presumed insensitivity. Although skill-based differences were found with integrant patterns, it should be noted that changes introduced to distracter integrant patterns were relatively small temporal deviations, whereas changes in distracter aggregate patterns were gross transpositions of whole groups of elements. The finer temporal resolution available to musicians is evidently no longer advantageous when it comes to detecting such large alterations.

Overall, current findings about the effects of complexity upon attentional flexibility paint a complicated picture. There is considerable inconsistency in how these findings measure up, not only against predictions, but also against the findings of Multipart Experiment 1. However, before concluding that the complexity has differential effects at encoding and retrieval, some methodological concerns need to be addressed. Specifically, two possible shortcomings of the retrieval task emerge. Both relate to the nature of the deviations introduced into distracter test items. First, deviations in distracter *integrant test items* may have disturbed proactive metric framework generation. Second, deviations in distracter *aggregate test items* may have contributed to a general lack of sensitivity on the part of the test. To overcome these apparent limitations, Multipart Experiment 3 continues the investigation of retrieval under prioritised integrative attending conditions in a reproduction task, which eliminates the need for distracter patterns.

## 6.4 Multipart Experiment 3: Simulated ensemble performance

### 6.4.1 Overview

Multipart experiment 3 employs a simulated ensemble performance paradigm to investigate the effects of integrant pattern retrieval upon the ability to attend to aggregate pattern structure. The reproduction-based paradigm was inspired by a form of ‘rhythmic canon’ developed by music pedagogue Jacques-Dalcroze. In its present version, the ‘lead’ part of the rhythmic canon is presented by computer (see Figure 6.13 & Track 60), and the participant is required to ‘follow’ this lead part by reproducing it at a lag interval (see Track 61). The lead part always consists of an antecedent/consequent (i.e., question/answer) pair of patterns, where the consequent follows the antecedent immediately, and both have the same overall duration. The task requires the participant to begin tapping the antecedent/consequent pair at the point when the consequent pattern begins in the computerised lead part. This produces a situation where the participant must attempt to (a) memorise the consequent pattern whilst reproducing the antecedent pattern, and then directly (b) reproduce the consequent pattern.

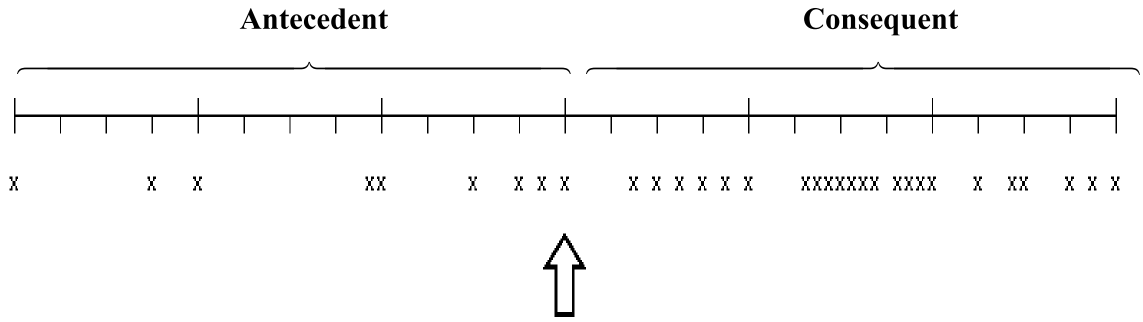


**Figure 6.13:** Structure of the rhythmic canon used in Multipart Experiment 3. The point at which participants are required to begin their reproduction of the antecedent/consequent pair is marked by the arrow.

It is assumed that this simulated ensemble performance paradigm provides a more sensitive index of processing efficiency than the recognition task in Multipart Experiment 2, because pattern reproduction, compared with recognition, allows for finer resolution when measuring accuracy. In the aggregate pattern recognition phase of the earlier experiment, listeners were required to respond to the reordering of groups of pattern elements that otherwise remained intact (i.e., within group relationships were preserved). In many cases, it would have been sufficient simply to note how target patterns start and finish, and then to compare this with the initial and final sections of memory test items. (The recency effects observed with aggregate patterns in Multipart Experiments 1 & 2 support this.) In contrast, the current reproduction task requires the formation of detailed representations of all temporal relations occurring throughout target patterns.

If it is assumed that antecedent patterns serve as target integrant patterns, and that consequent patterns serve as aggregate patterns, then prioritised integrative attending is required in the simulated ensemble performance paradigm to allow simultaneous antecedent pattern retrieval (to guide reproduction) and consequent pattern encoding. This is a slightly different variety of prioritised integrative attending to the type met in Multipart Experiment 2: trans-integrant grouping is no longer a strict requirement. In other words, it is not necessary for the attender to construct aggregate pattern structure by combining target and complementary integrant patterns, as the complete aggregate (i.e., consequent) pattern is given in singlepart form by the computer.[22] Nevertheless, the term prioritised

[22] Using complementary integrant patterns as consequent patterns would make the task, which is already difficult, nearly impossible.

integrative attending is still justified on the assumption that participants benefit from a strategy that involves the integration of their ongoing antecedent reproduction with the consequent pattern unfolding in the computerised part. Without such a strategy, these two aspects of the task would be temporally incompatible and mutually disruptive. In any case, the attentional demands met in real ensemble contexts are simulated more closely in the current task than in previous experiments: the individual must carry out a performance whilst remaining sensitive to what is going on around them. In fact, the task is in some ways reminiscent of types of musical interactions alluded to by respondents of the Ensemble Performance Questionnaire who work in the jazz/improvisation idiom (see 2.4.3.1.2).

The three multipart rhythmic complexity conditions used in Multipart Experiments 1 and 2 are duplicated in the current task by varying the relationship between antecedent and consequent patterns. In the *matched metrical* condition, antecedent and consequent patterns best fit the same meter, in the *mismatched metrical* condition, antecedent and consequent fit different meters, and in the *nonmetrical* condition, antecedent patterns are nonmetrical. To produce these conditions, quadruple aggregate patterns from the previous experiments are relegated to the status of consequent patterns, and the former quadruple, triple, and nonmetrical integrant patterns become antecedent patterns. Thus, across the three complexity conditions, situations arise where quadruple consequent patterns must be memorised whilst simultaneously retrieving quadruple, triple, or nonmetrical antecedent patterns.

In line with predictions for Multipart Experiments 1 and 2, it is expected that if metric frameworks facilitate processing efficiency at retrieval, then performance will be better (a) in metrical conditions than in the nonmetrical condition, and (b) in the matched metrical condition than in the mismatched metrical condition. Therefore, reproduction of both antecedent and consequent patterns should be most accurate in the matched metrical condition, followed by the mismatched condition, and least accurate in the nonmetrical condition.

## 6.4.2 Method

### 6.4.2.1 Participants

Participants were 12 professional percussionists. All had extensive experience as performers in symphony orchestras (e.g., *Sydney Symphony Orchestra*; *Australian Opera* *and Ballet Orchestra*) and smaller ensembles specialising in contemporary music (e.g., the percussion ensemble *Synergy*).

#### 6.4.2.2 Design

A 6 x (3) design was employed, where the between groups factor was *subgroup* (a, b, c, d, e, & f), and the within group factor was *multipart rhythmic complexity* (matched metrical; mismatched metrical; nonmetrical). The main differences between the current design and the designs of Multipart Experiments 1 and 2 is that the variables *musicality* and *test item type* have been dropped. The nature of the current task necessitates the exclusive use of highly skilled musicians and obviates the need for test items altogether. Another difference in designs is the increased number of subgroups here (see Appendix 6.19). This change was introduced to allow a large number of different stimulus patterns to be examined without necessitating excessively long experimental sessions. Therefore, to promote the external validity of findings across patterns, participants in different subgroups encountered different tokens of patterns in each multipart rhythmic complexity condition.

The main dependent variables were reproduction accuracy for (a) antecedent patterns and (b) consequent patterns. Reproduction accuracy is assumed to be an index of processing efficiency in the context of the present task. Auditory inspection time was used as an additional index of processing efficiency. Auditory inspection time was measured by examining the number of times participants chose to hear the antecedent patterns during a familiarisation phase (similar to auditory inspection time measures used in Singlepart Experiments 1 and 2).

#### 6.4.2.3 Stimuli and apparatus

As in Multipart Experiments 1 and 2, stimuli were taken from the 12 best rhythm sets identified by Singlepart Experiment 1. The ‘target integrant patterns’ from these rhythm sets served as antecedent patterns, and the ‘target aggregate patterns’ served as consequent patterns. Therefore, the entire stimulus pool consisted of (a) 12 quadruple antecedent patterns, (b) 12 triple antecedent patterns, (c) 12 nonmetrical antecedent patterns, and (d) 12 consequent patterns, each fitting a quadruple meter. These patterns were combined to form stimulus items in which a consequent pattern follows each antecedent pattern immediately (i.e., the final element of each antecedent, nee integrant, pattern is treated as the first element of the consequent, nee aggregate, pattern).

Three stimulus items were adapted from each of the 12 rhythm sets. In each item the consequent pattern belonging to the host set is preceded by either a quadruple, a triple, or a nonmetrical antecedent pattern, corresponding to the three multipart rhythmic complexity conditions. All patterns were presented at the same rate in which the time unit duration was 150 ms. Presentation rate was not varied between patterns as in the earlier multipart experiments to avoid issues regarding differences in motor timing constraints due to rate differences.

The apparatus consisted of the following units: (a) PowerBook 5300cs Macintosh computer; (b) MAX (version 3.0) software; (c) Pocket Macsi computer MIDI interface; (d) Roland MT-32 sound module; (e) Roland SPD-11 MIDI percussion pad; (f) Creative SBS-300 speaker; (g) a pair of drumsticks. These units were connected such that the MAX program could send MIDI noteout messages to the sound module, either in response to messages originating internally, or in response to a message indicating that the percussion pad had been struck. The output of the sound module was connected to the speaker (see Figure 6.14).

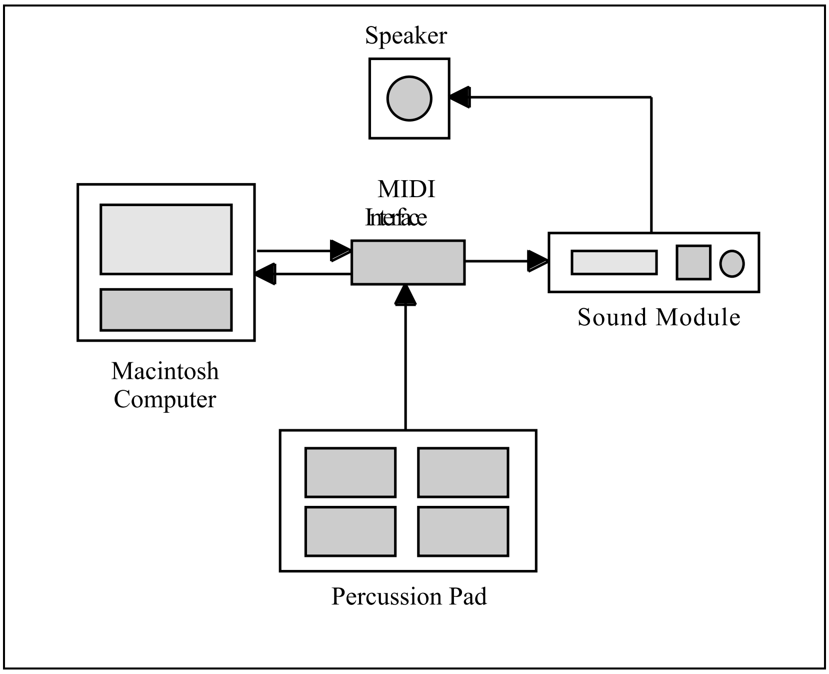


**Figure 6.14:** Equipment configuration for Multipart Experiment 3.

#### 6.4.2.4 Procedure

Each participant was tested at their private residence. The equipment was set up such that the percussion pad and computer were in a suitable position for operation by the participant.

The speaker was positioned directly in front of the participant. After instructions were given (see Appendix 6.20), the participant completed three blocks of practice trials, followed by six blocks of test trials. Each block consisted of two phases: a familiarisation phase and a test phase.

In the *familiarisation phase*, the participant was given the opportunity to become familiar with the antecedent pattern that was to be featured in the test phase of the current block. Clicking with the mouse on a button on the computer screen triggered one presentation of the antecedent pattern, which was articulated by a snare drum sound. Participants were instructed to listen to the antecedent pattern as many times as they required in order to memorise it. The number of times that participants chose to listen to the antecedent pattern was recorded by the computer.

The *test phase* consisted of three identical 'performance trials'. The task in each performance trial was based upon a form of rhythmic canon, where the computer presented the lead part and the participant followed. The lead parts consisted of antecedent/consequent pairs of patterns articulated by a snare drum sound (with a MIDI velocity value of 96). In each pair, the consequent pattern followed the antecedent pattern immediately. The transition from the antecedent to the consequent pattern was not signalled explicitly, but should have been assisted by familiarity with the antecedent pattern.

In each performance trial, the participant was instructed to begin reproducing (by tapping with drum sticks on the percussion pad) at the point when the consequent pattern began in the computerised lead part. Thus, the participant was required to listen to the (familiar) antecedent pattern, and then begin to reproduce it on the first element of the consequent pattern. Whilst reproducing the antecedent pattern, it was necessary for the participant to attempt to memorise the consequent pattern that was being presented concurrently by the computer, in order to allow their reproduction of the consequent pattern to follow immediately from their reproduction of the antecedent pattern. Thus, he or she was required to reproduce the antecedent/consequent pair, beginning from the end of the computerised presentation of the antecedent. Each strike of the MIDI drum pad produced a single cowbell sound (with a MIDI velocity value of 118).[23] The participant was required to press the spacebar on the computer keyboard to initiate each performance trial. To begin each successive experimental block, the participant clicked on a button that appeared on the

[23] Although participants were given the opportunity to change the loudness of the snare drum and cowbell sounds independently, none of them chose to make any adjustment.

computer screen. A different antecedent/consequent pair was presented in each block. The participant rested between each block (to reduce the risk of metricality carryover effects, which was especially important due to the constant presentation rate employed in this experiment)

#### 6.4.2.5 Data collection

A storage buffer (in the MAX program) reflecting activity originating at the MIDI percussion pad was sampled every 150 ms, starting 50 ms before the beginning of each of the computerised consequent patterns. If a tap occurred during one of these 150 ms sampling periods, a '1' was recorded. On the other hand, if a tap did not occur during a sampling period, a '0' was recorded. Thus, a string of '1's and '0's, representing the participant's reproduction of each antecedent/consequent pair of patterns, was obtained for each performance trial. Note that the tapped reproductions were 'quantised' so that the basic time unit was 150 ms, the same duration as the time unit underlying the computerised patterns.[24] However, the recording period began 50 ms before the time point where the first tap of the reproduction of the antecedent should have occurred (see Figure 6.15). This was to allow for anticipations of the veridical position of pattern elements. Although studies of tapping-synchronisation (e.g., Kolers & Brewster, 1985) typically find anticipations, or 'negative asynchronies', in the order of 57 ms, it was expected that they would not be so large in the present study, given the response method (tapping with a drum stick, rather than the usual finger or foot), and the expertise of participants. This expectation was confirmed in pilot tests, which revealed that responses were in fact more likely to lag behind veridical locations.

[24] This coarse quantisation value was chosen to allow for tempo drifts during consequent pattern reproduction (which was unaccompanied).

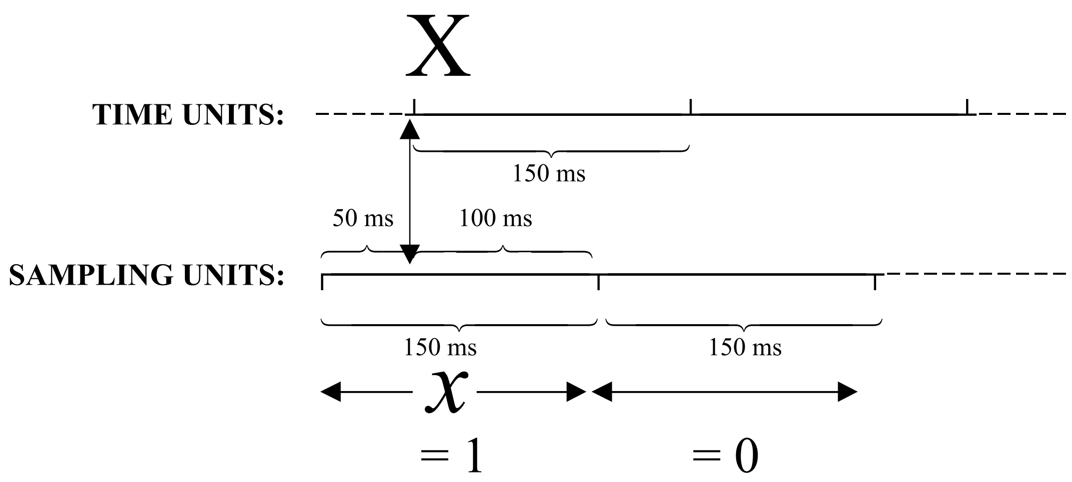


**Figure 6.15:** Relationship between time units and sampling units. X represents a pattern element in the computerised lead part, and *x* is an element in the participant's reproduction. Sampling units in which an element occurs are coded '1'. Empty time units are coded '0'.

In each performance trial, the recording period ended after 120 sampling periods (each of 150 ms duration) had elapsed. This overall duration allowed sampling units 1 to 49 to capture reproductions of the antecedent pattern, and sampling units 49 to 120 to capture reproductions of consequent patterns (sampling unit 49 belongs to both antecedent and consequent patterns as they 'overlap' – the final element of the antecedent pattern is the first element of the consequent pattern). Sampling units 98 to 120 were included to accommodate errors that resulted in the lengthening of pattern reproductions (e.g., rate decreases; errors of commission).

#### 6.4.2.6 Analyses

##### *6.4.2.6.1 Auditory inspection time*

A 6 x (3) ANOVA was conducted on the auditory inspection time data (i.e., the number of times that participants chose to hear antecedent patterns) that were collected during the familiarisation phases (see Appendices 6.21). As in earlier experiments, an item analysis was also conducted (see Appendices 6.22), but its results are reported only when they conflict with those from the conventional analysis. Orthogonal planned contrasts were used in all comparisons. Alpha was set at .05, and the critical value for $F(1,6)$ in both the conventional and the item analysis is 5.99.

##### *6.4.2.6.2 Reproduction accuracy*

Reproduction accuracy was measured by calculating the correlation between computer coded versions of each target consequent pattern (i.e., the consequent pattern presented by the computer) and its reproduction (i.e., the consequent pattern tapped by the participant). Specifically, correlation coefficients were computed between: (a) binary code versions of pattern reproductions that occupied the time period during which the antecedent patterns should have been tapped (sampling units 1-49) and similarly coded versions of the target antecedent patterns; (b) coded versions of pattern reproductions that occupied the time period during which the consequent patterns should have been tapped (sampling units 49-120) and coded target consequent patterns. It was necessary to append the coded versions of target consequent patterns with a string of 23 ‘0’s (thus creating time units 98-120) to increase the number of time units so that it matched the number of sampling units in the consequent reproduction codes.[25]

The above method of parsing the data string collected in each trial into a section representing the reproduction of the antecedent pattern, and a section representing the reproduction of the consequent pattern, relies solely upon sampling unit position. That is, those responses that occurred within the sampling period that spanned units 1 to 49 were taken to represent the antecedent pattern reproduction, and those responses during the sampling unit 49 to 120 period were taken to represent the consequent pattern reproduction. This ‘a priori’ method may have led to the incorrect parsing of data in cases where the participant did not begin their reproduction of either the antecedent or the consequent pattern at the correct sampling unit location (i.e., sampling unit 1 for antecedent patterns and sampling unit 49 for the consequent patterns). It is advisable to control for such deviations, as they may result in accurate, albeit ‘out of phase’ antecedent and consequent reproductions. Given that participants were encouraged to familiarise themselves with the antecedent patterns (and therefore should have known when to begin antecedent reproductions), it is likely that consequent pattern reproductions were more susceptible to this problem.

To ensure that analyses are not biased by errors involving phase-shifted consequent reproductions, the data strings were (in addition to the a priori sampling unit determined parsing) parsed ‘a posteriori’ into antecedent and consequent sections according to features of the reproductions themselves, such as figural groups and number of elements tapped. That is, the boundary between antecedent and consequent reproductions was located by the less rigorous post hoc method of ‘eyeballing’ the strings of binary code with a view to

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[25] Although these appended zeros affect the *absolute* value of the correlation coefficients, they do not affect how the correlations from different multipart rhythmic complexity conditions compare *relative* to one another.

identifying features that resembled those that appeared in the target pattern code strings. In most cases, the figural groups that marked the antecedent reproductions were easily discernible, and, therefore, the beginning of the consequent reproduction could be located with reference to these features. In the small number of cases where the boundary between antecedent and consequent reproduction was not so clear, arbitrary criteria such as number of taps and consistency in erring were considered. To check reliability, these cases were passed on to a second, independent judge, whose decisions were consistent in all cases with those of the first judge.

Separate 6 x (3) ANOVAs were then conducted on the correlation coefficients (averaged over the three trials within each experimental block) that represented reproduction accuracy in terms of the relationship between target and reproduced antecedent patterns (see Appendix 6.23), and target and reproduced consequent patterns both for sampling unit-determined (see Appendix 6.24) and for feature-determined (Appendix 6.25) versions of consequent reproductions.

In these analyses, the between groups factors were rhythm set group and metricality group (see Appendix 6.23), and the within group factor was antecedent pattern metricality. Orthogonal planned contrasts in the analyses examined the relationship between the accuracy of both antecedent and consequent pattern reproduction in (a) conditions where the antecedent patterns were metrical (matched; mismatched) versus the nonmetrical condition, and (b) the matched metrical condition versus the mismatched metrical condition. Item analyses were also conducted (see Appendices 6.26 & 6.27), but are only reported when their findings conflict with conventional analyses.

Alpha was set at .05, and the critical value for $F(1,6)$ is 5.99 in all analyses.

## 6.4.3 Results

### 6.4.3.1 Auditory inspection time during antecedent familiarisation

The auditory inspection time data are graphically represented in Figure 6.16. The ANOVA revealed that the number of times that participants chose to listen to nonmetrical antecedent patterns during the familiarisation phase was significantly greater than the number of times they listened to metrical antecedent patterns, $F(1,6) = 6.18$. The difference between the number of times that participants listened to quadruple and triple patterns was not significant according to the conventional analysis, $F(1,6) = 1.49$. However, this difference was significant in the item analysis, F(1,6) = 12.73. These findings suggest that auditory inspection time increased monotonically from quadruple pattern, through triple patterns, to nonmetrical patterns (although there was only a relatively small difference between the number of hearings required for quadruple and triple patterns).

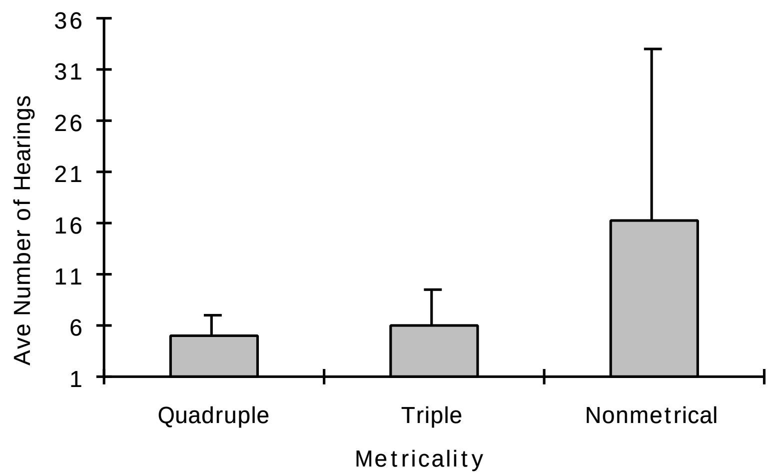



**Figure 6.16:** Number of times participants chose to hear antecedent patterns during the familiarisation phase.

#### 6.4.3.2 Accuracy of antecedent reproduction

The correlation coefficients obtained between target and reproduced antecedent patterns are shown in Figure 6.17. Strength of correlation is greater when the antecedent patterns were metrical than when they were nonmetrical, F(1,6) = 59.91. However, the difference between correlation strength for quadruple (matched metrical) and triple (mismatched metrical) patterns is not significant, F(1,6) = 0.55. These findings suggest that (a) metrical antecedent patterns were reproduced more accurately than nonmetrical antecedent patterns, but (b) reproduction accuracy was not affected reliably by whether antecedent patterns best fit the same meter as the concurrent consequent pattern.

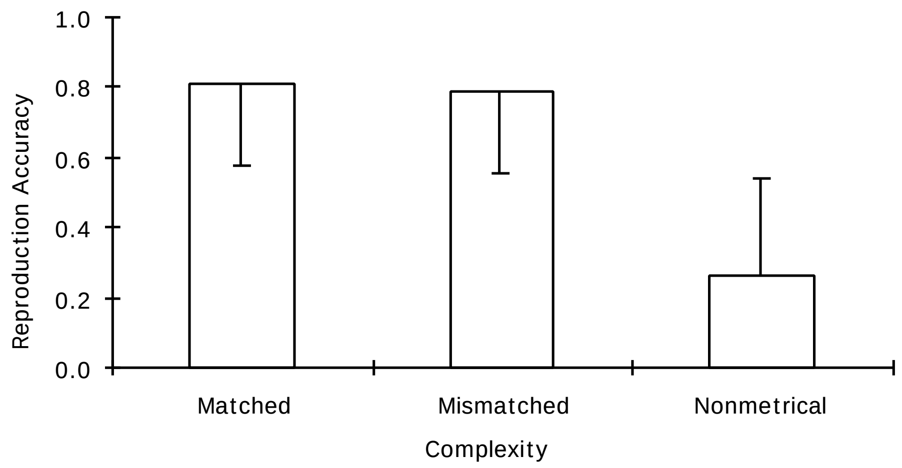



**Figure 6.17:** Correlations between target and reproduced versions of antecedent patterns.

### 6.4.3.3 Accuracy of consequent reproduction: A priori criteria

The correlation coefficients obtained between target and reproduced consequent patterns when consequent reproductions are parsed according to sampling unit determined location are shown in Figure 6.18.[26]

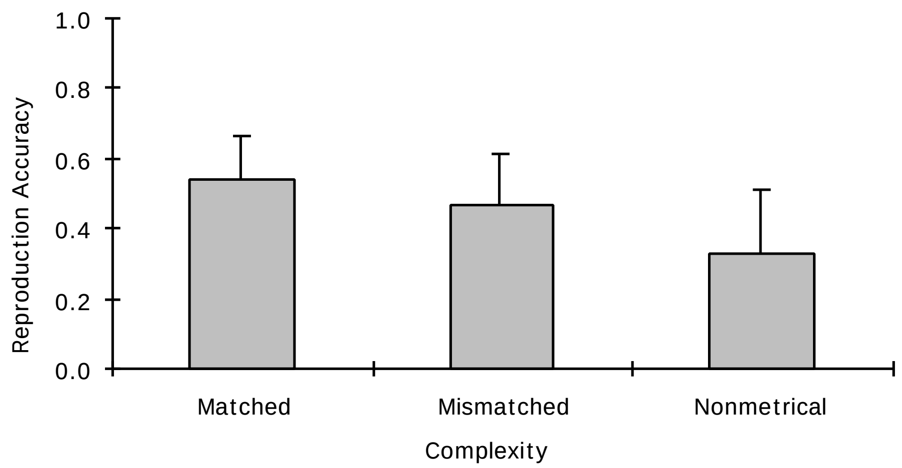



**Figure 6.18:** Correlations between target and reproduced versions of consequent patterns, where the location of consequent pattern reproductions is determined by sampling unit position.

Correlation strength is greater in metrical conditions than in the nonmetrical condition, $F(1,6) = 15.5$. However, the difference in correlation strength between target and

[26] Note that the absolute values of these correlations are not as important as their values relative to each another (see footnote 25).

reproduction for consequent patterns in matched metrical and mismatched metrical conditions is not significant, F(1,6) = 1.35. These findings suggest that, in accordance with predictions, consequent patterns were reproduced more accurately when the antecedent patterns being reproduced during their exposure were metrical, than when they were nonmetrical, but, contrary to predictions, whether the antecedent patterns matched consequent patterns in terms of metricality did not affect reproduction of the latter.

#### 6.4.3.4 Accuracy of consequent reproduction: A posteriori criteria

When consequent pattern reproductions were located (within each list of sampling units) by examining features such as figural groups in the reproductions themselves, the results are similar to when the location of consequent patterns was determined by considering sampling unit position only. Figure 6.19 shows the correlation coefficients obtained between target and reproduced consequent patterns using the feature-determined method of parsing. Reproductions of consequent patterns were more accurate in metrical conditions, than in the nonmetrical condition, F(1,6) = 16.54. In addition, similar to the situation where consequent pattern reproduction location was determined by sampling unit position, the difference in the accuracy of consequent pattern reproductions between matched and mismatched metrical conditions is not significant, F(1,6)= 2.41.

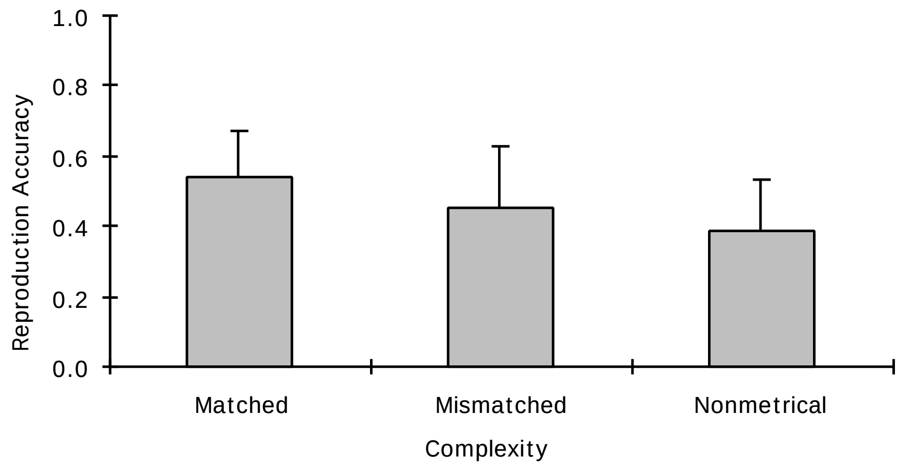



**Figure 6.19:** Correlations between target and reproduced versions of consequent patterns, where the location of consequent pattern reproductions is determined by feature analysis.

### 6.4.4 Discussion

In accordance with predictions, results indicate that metrical integrant (i.e., antecedent) patterns were processed more efficiently than nonmetrical integrant patterns. The former were listened to fewer times during familiarisation phases, but subsequently reproduced more accurately in the rhythmic canon task. The auditory inspection time findings provide evidence that meter promotes efficient encoding, and the reproduction findings demonstrate that this efficiency extends to retrieval. More conclusive evidence for efficiency at retrieval is seen in the effects of antecedent pattern metricality upon ability to simultaneously memorise consequent patterns. Greater interference to the process of aggregate pattern memorisation was produced by retrieval of nonmetrical integrant patterns, than by the retrieval of metrical integrant patterns. This suggests that, contrary to the confusing results of Multipart Experiment 2, proactive metric framework generation does aid prioritised integrative attending. Thus, when the current findings are placed beside those of Multipart Experiment 1, the benefits of metric framework generation to attentional flexibility in multipart contexts are similar at encoding (Multipart Experiment 1) and retrieval (Multipart Experiment 3).

Despite the presumed sensitivity of the current reproduction-based task, the present findings did not support the prediction that attentional flexibility is facilitated to the extent that integrant and aggregate patterns are compatible in terms of the meter they best fit. Accuracy at encoding quadruple aggregate patterns was commensurate with quadruple and triple integrant patterns. This finding is consistent with the results of Multipart Experiments 1 and 2. There was, however, some evidence for differential levels of processing efficiency associated with encoding quadruple and triple integrant patterns during familiarisation phases: auditory inspection time was shorter in the case of quadruple patterns. This finding replicates the results of Singlepart Experiment 2, and is suggestive of a binary bias in rhythm perception. Nevertheless, while there are advantages associated with learning isolated quadruple integrant patterns, these bonuses are not reflected in ability to engage in prioritised integrative attending. This invites the speculation that participants were not using full metric frameworks when they were required to divide attention between integrant and aggregate patterns in the context of the tasks in Multipart Experiments 1, 2, and 3. Perhaps, instead of recruiting metric hierarchies consisting of beat-level and bar-level pulsations, participants relied solely upon beat-level pulsations to specify pattern structure during prioritised integrative attending.

## 6.5 Multipart summary

On the whole, the three multipart experiments reported in this chapter support the hypothesis that metric frameworks enhance processing efficiency, and thereby facilitate prioritised integrative attending in multipart rhythmic contexts. Multipart Experiment 1 provides evidence that, when simultaneously *encoding* integrant and aggregate aspects of multipart patterns, the generation of metric frameworks associated with metrical integrant patterns enables an attentional strategy flexible enough to allow more than one part to be attended simultaneously. Surprisingly, a seemingly opposite finding emerged from Multipart Experiment 2, which investigated efficiency of integrant pattern *retrieval*, although it was argued that this inconsistency was an artefact of peculiarities associated with an overly contrived recognition task. Indeed, the outcome of Multipart Experiment 3, which investigated integrant pattern retrieval in a more ecologically valid reproduction task (the simulated ensemble performance paradigm) are consonant with the results of Multipart Experiment 1. Therefore, the attentional flexibility required for prioritised integrative attending is facilitated by both reactive (at encoding) and proactive (at retrieval) metric framework generation. Nevertheless, across all three experiments, performance was not affected by compatibility between integrant and aggregate patterns' best fitting meters. This implies that whether a metric framework simply is or is not generated is a more important influence upon attentional flexibility than the actual identity of the framework.

Attentional flexibility in multipart contexts was also affected by attending mode and musicality. The effects of attending mode were clear-cut in Multipart Experiment 2, where it was found that - in accordance with predictions – flexibility was more constrained under prioritised integrative attending conditions than under either selective or nonprioritised integrative attending conditions. Furthermore, Multipart Experiments 1 and 2 both yielded findings suggesting that musicians are capable of greater attentional flexibility than nonmusicians. In the former experiment, this superiority manifested itself in performance with aggregate patterns, whereas in the latter, it was more evident in performance with integrant patterns. Thus, the benefits of musical skill are not generalised, but vary markedly with task demands. The next chapter is concerned with explaining the observed effects of multipart rhythmic complexity, attending mode, and musicality.

# CHAPTER 7

# GENERAL DISCUSSION

Three sets of experimental findings are summarised in the first section of this chapter: (a) Ensemble Performance Questionnaire (EPQ) findings from Chapter 2, (b) results of the Singlepart Experiments in Chapter 5, and (c) Multipart Experiment results from Chapter 6. The implications of these findings are discussed with regard to music education, empirical research into rhythm, and theoretical accounts of attentional resource allocation in multipart musical contexts. Finally, a new theory of attentional resource allocation in musical ensemble performance (ARAMEP) is proposed.

# 7.1 Recapitulation: Stocktake of empirical observations

## 7.1.1 Summary of findings

The major empirical findings to emerge from the current investigation of the role of meter in attention to singlepart and multipart musical textures are listed below in point form. The findings speak to three main issues: (a) the nature of adaptive behaviour in complex multipart musical interactions such as ensemble performance, (b) the role of meter in promoting processing and representational efficiency when listening to singlepart rhythmic patterns, and (c) how meter – and other factors such as attending mode and musicality – enables attentional flexibility when listening and performing in the context of multipart patterns.

***A) Adaptive behaviour in multipart contexts: Ensemble Performance Questionnaire (EPQ) findings from Chapter 2.***

- Prioritised integrative attending (i.e., simultaneously attending to target integrant and aggregate aspects of multipart patterns) constitutes optimal (i.e., adaptive) behaviour in the context of ensemble performance. However, perceived importance of prioritised integrative attending varies with status: it is more highly valued by professional orchestral musicians and improvisers than by amateur orchestral musicians. Furthermore, amateurs are more likely than professionals to believe that prioritised integrative attending proceeds automatically.
- Prioritised integrative attending is especially important to achieve rhythmic cohesion in ensemble contexts. Professionals were more likely than amateurs and improvisers to mention this specific goal.
- Ability to engage in prioritised integrative attending is believed to be influenced more strongly by rhythmic complexity than by other musical factors.

***B) The processing and representation of singlepart patterns: Singlepart experimental findings from Chapter 5.***

- Metrical patterns are *processed* more efficiently than nonmetrical patterns.
    - → Auditory inspection time was shorter for metrical patterns than for nonmetrical patterns in tasks requiring listeners to (i) rate how well quadruple, triple, nonmetrical patterns fit various metric frameworks (Singlepart Experiment 1), and (ii) memorise quadruple, triple, nonmetrical patterns (Singlepart Experiment 2). In addition, auditory inspection time was shorter for quadruple patterns than for triple patterns in the memorisation task, suggesting a binary bias.

- Metrical patterns are *represented* more efficiently than nonmetrical patterns (Singlepart Experiment 2).
    - → Metrical patterns were recognised more accurately than nonmetrical patterns.
    - → Recognition accuracy was greatest for metrical patterns when accompanying context markers were consistent with their theoretical metricality, whereas context markers did not affect the recognition of nonmetrical patterns.
- Metric frameworks assist in *maintaining attention* as patterns unfold (Singlepart Experiment 2).
    - → A recency effect was observed in recognition accuracy for metrical patterns (indicating sustained attention), whereas a primacy effect occurred with nonmetrical patterns (indicating difficulty sustaining attention).
- *Musical skill* affects overall accuracy, metric biases, and proficiency at using metric hierarchies (Singlepart Experiment 2).
    - → Recognition accuracy for singlepart patterns was generally better in musicians than in nonmusicians.
    - → Musicians' recognition accuracy was greatest for quadruple patterns, which indicates a binary bias, whereas nonmusians recognised triple patterns most accurately, indicating a ternary bias.
    - → Compared with nonmusicians, musicians' performance indicates greater proficiency at generating beat-level pulsations implied by metrical patterns, and a greater tendency to exploit explicit bar-level markers as contextual cues.

***C) Processing efficiency and attentional flexibility in multipart contexts: Multipart experimental findings from Chapter 6.***

- Multipart rhythmic complexity affects processing efficiency, and thereby constrains attentional flexibility.
    - → Prioritised integrative attending involving simultaneously *encoding* target integrant and aggregate aspects of multipart pattern proceeds more efficiently (more accurate aggregate pattern recognition) when target integrant patterns are metrical than when they are nonmetrical (Multipart Experiment 1).
    - → Prioritised integrative attending involving simultaneous target integrant *retrieval* and aggregate encoding is more efficient (more accurate aggregate pattern reproduction) when target integrant patterns are metrical than when they are nonmetrical (Multipart Experiment 3). The opposite effect was observed in Multipart Experiment 2, but there is reason to believe that it was artefactual in this case.
    - → Prioritised integrative attending is not affected by whether or not target integrant and aggregate aspects of multipart patterns best fit the same meter (Multipart Experiments 1, 2, & 3).

- Attending mode affects attentional flexibility.

  → Recognition accuracy was lower under prioritised integrative attending conditions, than under either selective attending or nonprioritised integrative attending (Multipart Experiment 2).

- Attentional flexibility increases with increasing musical skill.

  → Musicians were more accurate than nonmusicians at recognising integrant patterns (Multipart Experiment 1) and aggregate patterns (Multipart Experiment 2).

- Attentional focus varies along the timecourse of multipart patterns.

  → Primacy effects were observed in recognition accuracy for integrant patterns, and recency effects occurred with aggregate patterns (Multipart Experiments 1 & 2). There was some indication that aggregate recency effects were more pronounced with metrical, than with nonmetrical, target integrant patterns.

### 7.1.2 Interpretation

The above findings testify in favour of an adaptive role of metric frameworks in multipart musical interactions. The implications of the EPQ findings regarding musicians' intuitions about the relationship between prioritised integrative attending and rhythmic complexity are realised nicely in the results of the singlepart and multipart experiments. Metric frameworks promote efficient processing and representation with singlepart patterns, and such efficiency is shown to be lucrative in relatively complex multipart contexts. In particular, the multipart findings suggest that processing efficiency associated with meter facilitates attentional flexibility, and thereby enables simultaneous attention to target integrant and aggregate aspects of multipart patterns. Put another way, integrant patterns that do not conform with metric structure (nonmetrical patterns) tend to be processed inefficiently, and hence interfere with aggregate pattern processing.

The beneficial effects of meter on prioritised integrative attending appear robust, as they are evident in task situations characterised by proactive and reactive metric framework generation alike. Thus, meter plays similar roles in performance (involving retrieval of target integrant patterns) and listening (involving target integrant encoding) in multipart contexts. In further support for the robustness of the benefits of meter, it does not appear crucial whether integrant and aggregate patterns are matched in terms of their respective best fitting metric frameworks. Likewise, meter does not discriminate on the basis of musical skill when it comes to its effects upon ability to engage in prioritised integrative attending. Although musicians are more proficient than nonmusicians in their use of metric frameworks in singlepart contexts, and display greater attentional flexibility overall in multipart contexts, their prioritised integrative attending ability does not indicate heightened sensitivity to the benefits of meter. In addition to the effects of meter, attentional flexibility varies as a function of attending mode and location within the timecourse of an unfolding pattern.

These empirical findings highlight intimate links between attentional processes and the temporal structure of external event sequences. This is reminiscent of the dynamic attending approach (Jones, 1976; Jones & Boltz, 1989; Large & Jones, 1999), but the current findings encourage an extension of dynamic attending claims from contexts that demand selective and nonprioritised integrative attending, to situations involving prioritised integrative attending. Indeed, prioritised integrative attending, and the multipart contexts in which it is invoked, have not been addressed adequately in any of the existing models of rhythmic behaviour. Applying dynamic attending concepts to current multipart findings suggests that metric frameworks provide an attentional scheme that guides the processes involved in prioritised integrative attending. However, when the process of metric framework generation is disturbed, processing becomes inefficient and largely incompatible with flexible attentional strategies that foster prioritised integrative attending. This conception of the role of meter has implications for three main areas: music education, empirical research into rhythm, and theory development. These are considered in the next section.

## 7.2 Implications

### 7.2.1 Music education

The postulated relationship between metric frameworks and attentional processes has implications for the development of music education techniques for fostering prioritised integrative attending skills in ensemble performance. Techniques that teach proficiency at using metric frameworks may be particularly useful when introducing young children to ensemble performance. Importantly, such techniques may benefit not only rhythmic ability, but also other skills relevant to ensemble performance.

It seems that young children often experience difficulty paying attention to parts played by others in ensembles (Casey, 1991). As shown in Chapter 2, much research has addressed this issue indirectly by seeking to identify predictors of student participation and achievement in ensembles (Humphreys et al., 1992). Some of this work has pointed to rhythmic abilities (e.g., Young, 1971), and a couple of the many existing informal techniques aimed at improving prioritised integrative attending skills address rhythm (Campbell, 1991; Casey, 1991). This raises questions about developmental aspects of rhythmic behaviour.

It is difficult to pinpoint the age, or stage in cognitive development, at which children become proficient in using meter. In an early study, R. Jones (1976) concluded that children gain access to full metric hierarchies (i.e., both beat-level and bar-level pulsations) at around 9.5 years of age. Nevertheless, more recent evidence suggests that children are capable of using meter at a younger age. Some have argued that children understand both figural and metric aspects of rhythm very early in development, and that musical training and task context dictates which of these aspects guides behaviour (Bamberger, 1982, 1991, 1994; Smith et al., 1994; Upitis, 1987) (see 3.4.3.2.2). However, full metric understanding (incorporating beat- and bar-level pulsations) is yet to be demonstrated in children younger than 6 years (Smith et al., 1994). Hargreaves (1999, p. 161) argues that "2-5-year-olds are more likely to make 'figural' than metrically accurate representations simply because of their level of development, and that these may well incorporate some metrical inaccuracy". Consistent with this timecourse, several studies have shown that 5-year-olds are sensitive to low level metric periodicities such as beat-level pulsations and beat subdivisions (Drake, 1993; Drake & Gérard, 1989), and Dowling (1999) claims that these metric levels are evident in the spontaneous songs of 2-year-olds (although he does not cite evidence for this or indicate the reliability of these displays). Even very young infants exhibit robust rhythmic pulse-related behaviour (Trevarthen, in press).

Thus, it appears that below the age of about 6 years, children may have access to beat-level but not higher level metric periodicities. In support of this notion, children appear unable to reproduce intensity differences reflecting high-level metric accents until about 9 years (Drake, Dowling, & Palmer, 1991; Gérard & Drake, 1990). Even when children do gain access to higher metric levels, flexibility at shifting attention between these levels and adjusting to changing periodicities may be developmentally restricted. In a discussion of evolutionary considerations in temporal behaviour, Richelle, Lejeune, Perikel, and Fery

(1985, p. 95) propose that "age and development may not be critical with respect to accuracy of temporal regulations, but to the flexibility of timing systems".

Some have argued that there is confusion in the literature on the metric ability of children due to methodological concerns and narrow conceptions of what constitutes musical behaviour (Smith et al., 1994; Walker, 1987). Indeed, studies that exercise caution at least with regard to methodology have revealed that children's perception of music is guided by metric principles, although their rhythmic productions may in some cases fail to reveal metric underpinnings (Gérard & Drake, 1990; see Smith et al., 1994). Thus, metric perception seems to precede robust metric production. Perhaps reactive metric framework generation emerges earlier in ontogeny that proactive metric framework generation.

Prioritised integrative attending rests upon relatively sophisticated metric abilities, and their enhancement of attentional flexibility. Given children's questionable ability to (a) generate high-level metric pulsations, (b) shift between metric levels, and (c) generate metric frameworks proactively, it is hardly surprising that young children appear to find prioritised integrative attending challenging. Thus, an immature metric sense translates into difficulties in ensemble performance. If this connection is valid, then training in the basic skill of using metric frameworks should set the groundwork for more advanced prioritised integrative attending skills. There are several successful music educational techniques for developing metric skills (e.g., Cuddy & Upitis, 1992; Jacques-Dalcroze, 1915, 1921; Radocy & Boyle, 1988). Exploring the effects of these techniques specifically upon prioritised integrative skills would be a worthwile topic for future research.

### 7.2.2 Empirical research into rhythm

The current conception of meter also specifies the requirements to be satisfied by models of rhythmic behaviour intended to account for interactions with complex multipart textures. These models should account for the interdependent manner in which target integrant and aggregate patterns are both processed and represented. Thus, model architecture should accommodate dynamic real time processes (e.g., cognitive/motor schemas like metric frameworks), as well as multidimensional memory representations (e.g., performance goals and plans – see 3.4.2.1.2).

Recognising the role of meter also engenders care when selecting experimental methods to evaluate models of rhythmic behaviour, as well as when interpreting the results of such empirical evaluations. On both counts, it is prudent to consider the degree to which the experimental task in question assesses efficiency of processing and efficiency of representation. In some cases, a dissociation between processing and representational efficiency might be expected. The performance of off-beat sequences serves as an example. In these sequences, the performer is required to produce an isochronous sequence that is phase shifted relative to a beat period so that their sounds occur only at the midpoint between beats (see Vos & Helsper, 1992). In traditional ‘Oom-Pah-Oom-Pah’ accompaniments to march tunes, the ‘Ooms’ and the ‘Pahs’ are usually assigned to separate instrumental parts. Musicians performing the ‘Pahs’ are said to be playing off-beats. Given that march tunes are typically in duple meter, the most efficient memory representation of an off-beat sequence occurring within the context of a march would probably contain the elements shown in Figure 7.1. There is little reason to suppose that musical skill would markedly affect the way in which such a simple sequence is organised in a performer’s memory. However, the efficiency with which such sequences are processed during performance does appear to vary with skill.

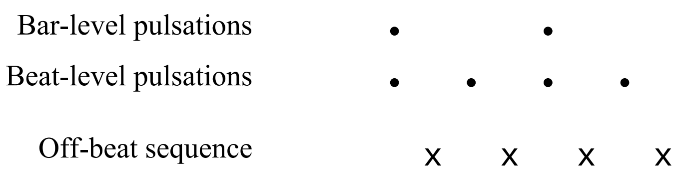


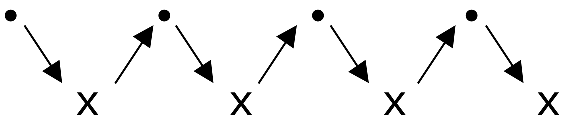

**Figure 7.1:** Two-bar off-beat sequence in duple meter.

The performance of off-beats presents difficulties for novice musicians, who display a tendency to drift onto the beat. This occurs partly because novices tend to concentrate on beat-level pulsations during off-beat performance, i.e., they use the beat-level as a referent. Indeed, they are usually quite explicit in their attempts to generate beat-level pulsations (often they feel the need to tap their foot, or even grunt in synchrony with the beat), and to anchor each off-beat to its preceding beat. At fast tempi, this strategy is cognitively intensive as it involves shifting attentional focus rapidly between beats and off-beats.

In contrast, there is anecdotal evidence that experts use bar-level pulsations as the referent during off-beat performance. This strategy is less intensive because anchoring *groups* of off-beats to bar-level pulsations necessitates less frequent shifts in attentional focus. This is consistent with the idea that skilled musicians are more adept at using higher metric levels

(Singlepart Experiment 2; Jones & Yee, 1997). Thus, it appears that experts employ a more efficient processing strategy than novices when performing off-beats (see Figure 7.2). If this distinction in strategy is considered in terms of novices experiencing a subjectively faster tempo (by focusing on beats rather than bars), then the described difference in behaviour conforms with the finding that performers lose voluntary control over off-beat tapping at high speeds (Vos & Helsper, 1992).

**Novice processing strategy**



**Expert processing strategy**

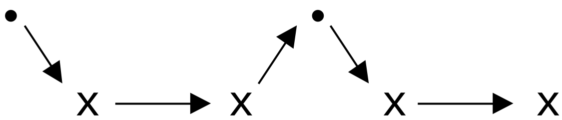


**Figure 7.2:** Diagrammatic comparison of novice and expert strategies for off-beat performance. Note that experts may use even higher level pulsations to segment the ongoing off-beat sequence, for example, into groups of four.

Not much solid evidence for the dissociation of processing and representational efficiency emerged from the current series of experiments. The only hint of such an effect occurred in Singlepart Experiment 2, where quadruple patterns were more efficiently processed than triple patterns (in terms of auditory inspection time) by both musicians and nonmusicians, while representational efficiency (indexed by recognition accuracy) was best for quadruple patterns in musicians and triple patterns in nonmusicians. One interpretation of these findings is that musicality exerts greater influence upon representational efficiency than processing efficiency in the context of the task in question. However, issues pertaining to the behavioural measures employed in that task need to be considered. Specifically, it may be misleading to compare these measures of processing and representational efficiency directly as they probably differ in sensitivity. Moreover, it could be argued that neither provide a pure index of what they purport to measure.

An alternative approach to investigating the independence or otherwise of processing and representational efficiency is to use neurophysiological measures. Techniques for measuring electrical activity in the brain, such as electroencephalography (EEG) and evoked potential (EP), and neuroimaging techniques such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI), may be useful in this regard. These techniques all provide a relatively direct means for recording brain activity related to perceptual and cognitive processing, but each has unique advantages. For example, PET has good spatial resolution (ranging within a few millimeters), but poor temporal resolution (1-2 s), and is therefore suitable for locating active structures but not for gathering a temporal profile of the activity. On the other hand, EEG and EP have high temporal resolution (within millisecond range) but low spatial resolution (constrained by electrode size and placement) and a poor signal-to-noise ratio (Regan, 1989). So, although EEG and EP reveal the timecourse of activity, they require many stimulus repetitions and do not pinpoint the precise location at which it takes place. A fairly good compromise is provided by fMRI, which has 1-2 mm spatial resolution and less than 1 s temporal resolution. Another more recent alternative with even better temporal resolution is provided by the steady-state probe topography technique (SSPT), which utilises the steady-state visually evoked potential (SSVEP) (see Silberstein, 1995). It is also possible to use certain techniques in concert, and thus obtain multiple neurophysiological measures simultaneously.

There is a strong tradition of using neurophysiological techniques to study musical behaviour and audition in general (e.g., Basso, 1999; Breitling, Guenther, & Rondot, 1987; Critchley & Henson, 1977; Marin & Perry, 1999; Nataanen & Alho, 1995, 1997; Pantev, Oostenveld, Engelien, Ross, Roberts, & Hoke, 1998; Peretz & Morais, 1993; Janata, 1995; Petsche, Lindner, Rappelsberger, & Gruber, 1988, Sergent, 1993; Zatorre, Halpern, Perry, Meyer, & Evans, 1996). Some studies specifically address rhythmic behaviour (e.g., Harris, Silberstein, Pipingas, & Pressing, 1998; Penhune, Zatorre, & Feindel, 1999). For example, Harris et al. (1998) studied auditory grouping principles by measuring cortical activity (using SSVEP) in response to sequences consisting of short and long duration tones.

If used in conjunction with behavioural measures, neurohysiological techniques may provide a means for teasing apart the contributions of processing and representational efficiency upon the accuracy of rhythmic behaviour. Neuroimaging techniques have been used specifically to ‘observe’ brain activity associated with processing (Fletcher, Shallice, Frith, Frackowiak, & Dolan, 1998; Hillyard, Teder-Saelejaervi, & Muente, 1998; Kent, 1998; Schacter & Buckner, 1998; Vaina, Cowey, & Kennedy, 1999; Wagner, Poldrack, Eldridge, Desmond, Glover, & Gabrieli, 1998; Zarahn, Aguirre, & D'Esposito, 1999). Techniques with high temporal resolution, in particular, provide a relatively pure index of processing activity as it progresses in close to real-time. When the profile of these neurophysiological measures is compared with the results of corresponding behavioural measures (i.e., behavioural responses obtained simultaneously with the brain recordings), any differences can be assumed to be due, at least in part, to representational factors. The behavioural profile (which is presumably affected by both processing and representation) minus the neurophysiological profile (an index of processing) should thus result in information about the representation. Thus, the effects of processing may be partialed out to isolate residual effects of representational efficiency.

Such comparison of neurophysiological and behavioural measures appears promising, but there are some points of caution which should be borne in mind. Caution in selecting the experimental task is necessary to ensure that extraneous variables related to response execution do not contaminate the data, as the type of response required by the experimental task has been found to affect neurophysiological output (Janata, 1995). Care must also be taken to select behavioural measures that can be compared readily with the neurophysiological data, and to employ appropriate statistical techniques when making the comparisons (e.g., time-series analysis; see Gregson, 1983; Schubert, 1999). Some researchers have already begun to address these types of methodological challenges (e.g., Harris et al., 1998; Sasaki & Gemba, 1982, 1993), but the issue of teasing apart processing and representation is yet to be addressed specifically.

### 7.2.3 Theoretical issues in attentional resource allocation in multipart contexts

#### 7.2.3.1 Temporality and flexibility in resource allocation

Above in section 7.1.2, a rudimentary explanation based upon Jones' dynamic attending principles (Jones, 1976; Jones & Boltz, 1989; Large & Jones, 1999) was offered for the current experimental findings. This explanation emphasised the plasticity of attentional processes by arguing that metric framework generation leads to the efficient distribution of attentional energy across time. There are further implications of this plasticity for gaining a deeper understanding of the way in which attentional resources are allocated in multipart musical interactions.

It was argued in Chapter 3 that traditional, essentially atemporal, resource theories do not take into account the relative timing of component tasks. Although atemporal resource theories may be comfortable with the tracking, representation formation, and memory retrieval components of prioritised integrative attending (see 3.4.3), they are not equipped for real time trans-integrant grouping. It is for this process in particular that a high degree of flexibility and temporal sensitivity in resource allocation is necessary. In short, the real time and continuous aspects of processing must be respected.

In the current experiments, the quadruple, triple, and nonmetrical target integrant patterns used in multipart stimuli were composed of identical figural groups of elements, albeit spaced differently such that periodic element placement occurred only in metrical conditions (see 4.4.4.2.1). The intimate link between attentional flexibility and temporal structure is underscored by the fact that even slight changes in temporal relation between these figural groups had pronounced effects on attentional flexibility. Further evidence for dynamic resource allocation across time can be seen in the primacy and recency effects observed in the listening-based multipart experiments (1 & 2). Given these inherently temporal phenomena, dynamic attending theory provides a firm basis for understanding attentional resource allocation in multipart rhythmic contexts.

Dynamic attending theory proposes that attentional resources are mobilised in accordance with dynamic expectancy schemes such as those that underlie metric frameworks. Therefore, it is not necessarily the case that an *overall greater amount* of resources are available for aggregate pattern processing when target integrant patterns are metrical, than when they are nonmetrical. Rather, metric frameworks associated with attention to metrical target integrant patterns encourage processing resources to be used more efficiently in a manner that permits greater attentional flexibility. An extension of this claim to present circumstances suggests that the manner in which attentional resources are deployed during prioritised integrative attending mirrors metric structure.

In accordance with dynamic attending views, it is currently assumed that an uneven distribution of resources is produced across metric locations because strong metric locations attract attentional resources, drawing them away from weaker metric locations.

These fluctuations in level of attentional activity may correspond to the ‘waves of attention’ referred to in early investigations of temporal perception (Bolton, 1894; Helmholtz, 1874; James, 1890/1950; Seashore, 1938/1967). More recent dynamic attending conceptualisations similarly emphasise such attentional plasticity. For instance, Large and Kolen (1994, p. 29) speak of “pulses of attention”, and Jones (1981, p. 571) describes how the attender “generates trajectories that cast out attentional thrusts” across pitch space and time regions. Furthermore, Jones’ (1982, 1990) characterisation of expectancy schemes as ‘attentional anchor points’ implies that these ‘attentional thrusts’ span regions between the crests of the hypothetical ‘attentional waves’. These attentional metaphors are consistent with the notion that there is a greater concentration of resource activity at strong metric locations than at weak locations. Accordingly, Gjerdingen (1989, p. 78) has described “the phenomenon of metrically modulated attention… For the psychologist or music theorist observing the listener, it might well appear that the listener was consciously ‘paying more attention’ to events occurring on strong beats, even though the phenomenon was brought about by a mostly automatic, low-level process”. Thus, *resource activity* mirrors the topography of metric frameworks.

The concept of fluctuating resource activity is adequate in explanations of selective attending and nonprioritised integrative attending (e.g., Jones et al., 1995; Klein & Jones, 1996), but is not entirely sufficient for explaining attentional resource allocation under prioritised integrative attending conditions. If it is assumed that resources are limited (see Kahneman, 1973; Wickens, 1980, 1984), then an increase in resource activity at strong metric locations would bring resource consumption closest to full capacity at these points in time. This logically would lead to a scarcity of resources necessary for trans-integrant grouping at strong, relative to weak, metric locations. In other words, only at strong locations would resource activity approach limits set by *resource availability* (see Figure 7.3). Therefore, success at prioritised integrative attending would be compromised at these locations.

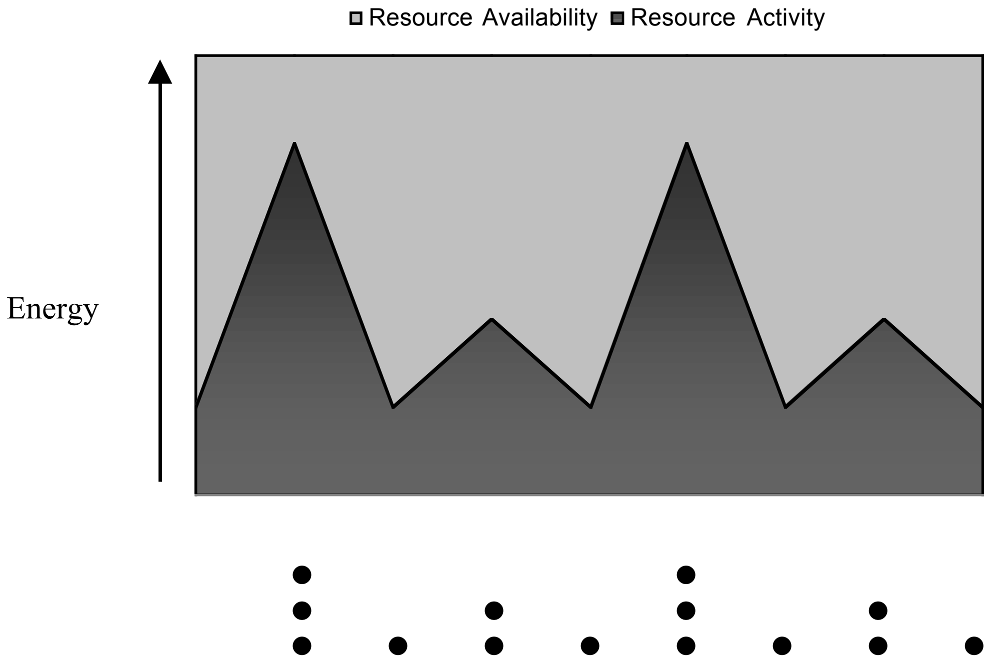



**Figure 7.3:** Resource activity as a function of metric location. The dots represent metric pulsations.

Although the current experiments did not investigate this proposition, it is counterintuitive, as it implies that it should be most difficult for ensemble performers (or listeners) to pay attention to complementary integrant patterns at strong metric locations. It seems unreasonable to expect that ensembles should 'fall apart' at strong locations, but be 'tight' at weak locations.

Neither has this issue been addressed directly by other empirical research. However, some related topics have been studied, such as asynchrony in ensemble performance (Rasch, 1979, 1988; Shaffer, 1984). These studies examined the degree to which performers in ensembles align the onsets of notes that, according to the musical score, are supposed to sound simultaneously. Although asynchrony has not been examined as a function of metric location, informal inspection of data reported by Shaffer (1984) suggests that asynchrony is not, on average, greater at strong than at weak locations. This observation is interesting because it was found in this study, and in many others, that expressive timing deviations within individual parts are greater at strong locations (see 1.2.2.3): there is a "tendency to slow on metrically stressed beats" (Shaffer, 1984, p. 589). Because asynchrony does not appear to increase at these locations, it is as if the increases in timing variability are being compensated for by enhanced attentional flexibility at strong metric locations. However, this is not entirely consistent with the idea that resource availability remains constant while resource activity goes through its course of alternating increases and decreases. Therefore, in order to account for flexible resource allocation during prioritised integrative attending, it becomes necessary to postulate plasticity in resource availability that offsets momentary fluctuations in resource activity. This leads to a two-factor conception of resources.

#### 7.2.3.2 Two-factor account of attentional resource allocation

##### *7.2.3.2.1 Resource availability and resource activity*

The two-factor account of attentional resource allocation specifies how variations in *resource availability* compensate for fluctuating *resource activity*. Resource availability refers to the proportion of the attender's resources that are free to serve in a given task at a particular point in time. Resource activity refers to the proportion of the attender's available resources that are actually employed in the service of the task. In the present conceptualisation, it is assumed that resource availability is finite at any given point in time. It is further assumed that, logically, resource activity is limited by resource availability. It should be noted that although the limited capacity assumption is commonly accepted, some have argued that it is neither useful (Allport, 1980) nor justifiable from a neurophysiological perspective (Neumann, 1987) (also see Meyer & Kieras, 1997a). Nevertheless, its retention in the current conception is justified on grounds that prioritised integrative attending is a sophisticated composite of various sub-skills (tracking, trans-integrant grouping, and memory retrieval), each entailing strict real time constraints and running continuously in parallel. At the very least, the memory component of prioritised integrative attending must be limited.

##### *7.2.3.2.2 Metrical contexts*

It is proposed here that both resource availability and resource activity hold potential to be modulated in a manner that is highly plastic. In musical contexts, this potential is released by the generation of metric frameworks. Metric framework generation allows resource availability and resource activity to be modulated efficiently in tandem. This proposal is based upon several assumptions.

First, availability fluctuates across timepoints in a manner that mirrors the profile of metric frameworks if an appropriate cognitive/motor schema is invoked (see Figure 7.4). As there is evidence that these schemas become more refined with increasing musical skill

(Singlepart Experiment 2), resource availability profiles should be more resolved and optimal in musicians than in nonmusicians. Such availability profiles may have contributed to the superior performance of musicians in the multipart experiments requiring prioritised integrative attending.

Second, the default pattern of resource activity mirrors the distribution of resource availability across time. Furthermore, activity is regulated by a feedback mechanism that is sensitive to availability limits, and thus functions to ensure that activity remains – insofar as task priorities permit – within these limits (see Figure 7.5). This feedback mechanism is analogous to the adaptive self-regulatory control systems used in engineering and cybernetics – a mundane example being the thermostat in air-conditioning units. Numerous relevant biological control processes that likewise function to maintain homeostasis have been found in human physiology (Ebenholtz, 1986; Miller, 1982; see Pressing, 1998, 1999; Woods, 1991), and it has been postulated that similar processes may even regulate relatively high-level 'thought' (Ito, 1993).

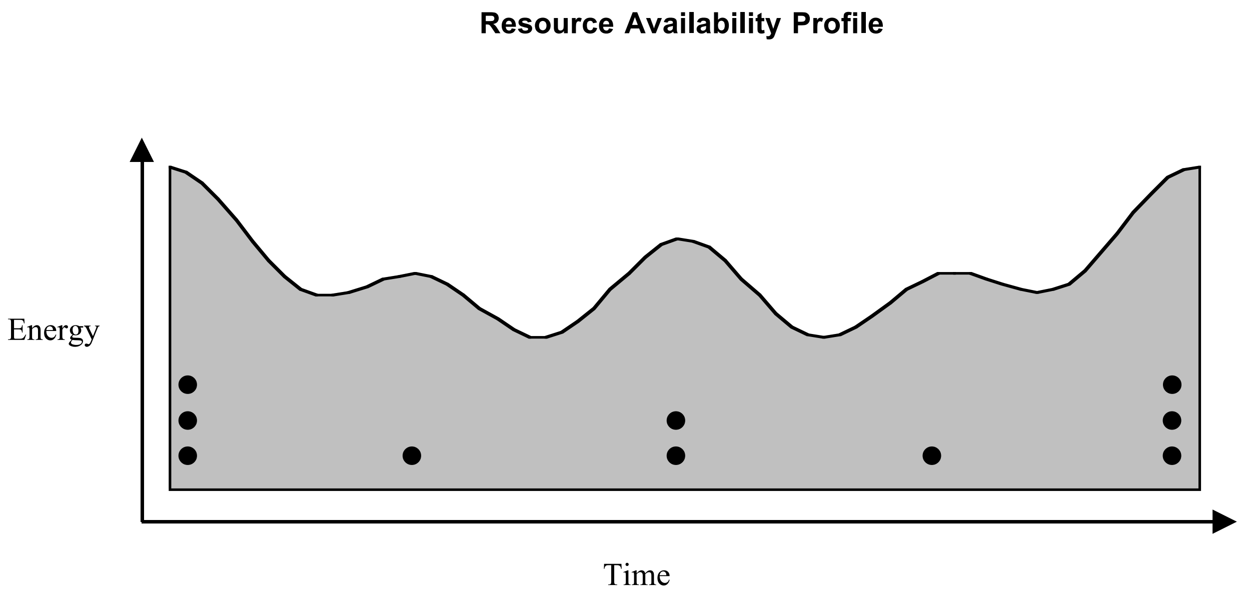



**Figure 7.4:** Resource availability distributed across time in a manner that that mirrors metric structure.

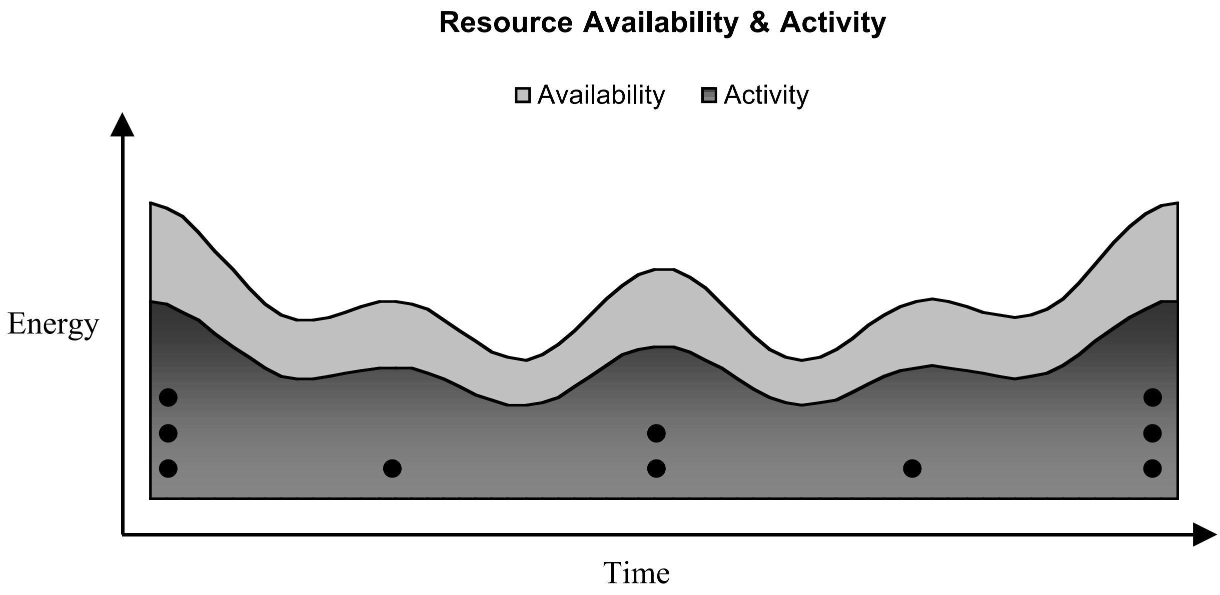



**Figure 7.5:** Both resource availability and resource activity mirror metric structure.

The tight relationship between resource availability and resource activity described above enables the efficient processing of metrical patterns. In accordance with the oscillator model of Large and Jones (1999), it is assumed here that resource activity becomes focused at space/time regions where target events occur, or are expected to occur (see also ten Hoopen, 1996). There is considerable variability in the concentration of events at different metric locations in music. Events are statistically most likely to occur at strong metric locations, such as the beginning of bars and beats, than at weak locations (Palmer & Krumhansl, 1990). Therefore, resource activity is usually increased at strong locations. When resource availability and resource activity operate in concert, however, compensatory increases in availability accompany the momentary increases in activity. Thus, sufficient resources are available so long as the pattern continues to conform to the established metric structure, as a greater proportion of resources is 'on standby' at strong metric locations.

This account differs from recent versions of the dynamic attending theory (Large & Jones, 1999) and its relatives (Desain, 1992; Large & Kolen, 1994) mainly in that it addresses resource availability, in addition to resource activity: both factors come to share metric structure. Therefore, metric frameworks are a blueprint for resource availability, as well as resource activity.

The current two-factor conception of resources becomes particularly useful when attempting to explain resource allocation in multipart rhythmic contexts. It is proposed that prioritised integrative attending in multipart patterns with *metrical* target integrant patterns is facilitated by the correlation between metric location and changes in resource availability and resource activity. At weak metric locations, resource activity associated with processing the target integrant pattern is typically low, and therefore the attender is free to focus on the complementary integrant pattern. At strong metric locations, even though resource activity associated with processing target integrant patterns is higher, attending to complementary integrant patterns is enabled by increased resource availability. Thus, the efficient distribution of attentional resources provides a foundation for flexibility in attending. Although the multipart experiments reported in Chapter 6 do not address specifically moment by moment variations in the focus of attention, it is easy to imagine how such variations may be useful in real ensemble contexts. For example, peaks in resource availability at strong metric locations would permit performers to increase resource activity at these locations in order to process, and react to, expressive timing deviations in other performers' parts.

In the present conceptualisation, however, there are circumstances under which availability and activity may operate independently. These include situations where (a) activity is deliberately, and effortfully (because it goes against the regulatory feedback assumption), focused at low availability regions, (b) external conditions unexpectedly attract activity, and/or (c) metric framework generation is not initiated or fails to be maintained. These situations are brought about by various circumstances. Deliberate activity at low availability regions may arise when listening for cues in other parts at weak metric locations (e.g., when attempting to coordinate with other players at the midpoint of a bar). Unexpected resource mobilisation may occur in the context of unfamiliar musical pieces, in response to performance errors, or in response to a surprising event in the periphery – syncopation, for instance. Indeed, this situation evidently occurred in Multipart Experiment 2, where the changes made to metrical target integrant patterns in order to convert them into distracter items proved quite disruptive. Finally, failure to generate a metric framework is relevant in situations involving attention to nonmetrical patterns.

#### *7.2.3.2.3 Nonmetrical contexts*

It is proposed that in multipart patterns with *nonmetrical* target integrant patterns, resource activity and resource availability become decoupled, and thus resources are distributed in a manner that is not conducive to prioritised integrative attending. Expectations about the temporal location of events comprising nonmetrical patterns lack precision. That is, although events may be expected, the attender has trouble determining precisely *when* they should occur – there is greater temporal uncertainty.

Phenomenally for the attender, the number of potential temporal locations at which the events could occur is greater than in metrical patterns. Therefore, in order to attentionally capture the events, there must be a corresponding increase in the size of the temporal region during which the attender is prepared for the events. As is the case in metrical patterns, this preparedness is manifested as increased resource activity. However, in nonmetrical patterns, these relatively high levels of resource activity must extend over regions of greater duration than those circumscribed by strong locations in metric frameworks.

Based on the assumption that sustained focused activity is effortful and leads to decreases in resource availability, the present account predicts that adequate increases in resource availability are not sustainable over the extended regions of high resource activation demanded by nonmetrical patterns. This is similiar to fatigue effects in more general task domains, such as decrements in cognitive functioning following sustained attention under a variety of circumstances (Koelega, 1996). Small-scale fatigue was evident in Singlepart Experiment 2, where recognition accuracy was superior for earlier portions of nonmetrical patterns (the primacy effect).

Decoupling of resource availability and resource activity is not only caused by the effects of nonmetrical structure upon activity. It is also assumed that availability is not modulated systematically in the case of nonmetrical patterns. Specifically, availability is constant over time, or fluctuates randomly, in the absence of schema use or certain physiological change (e.g., arousal due to extramusical stimuli). So, in the absence of metric framework generation, resource activity fluctuates wildly but corresponding fluctuations do not occur in resource availability (see Figure 7.6). Eventually, availability would begin to decrease monotonically (this is not shown in Figure 7.6) due to the relationship between availability and sustained focused activity described above.

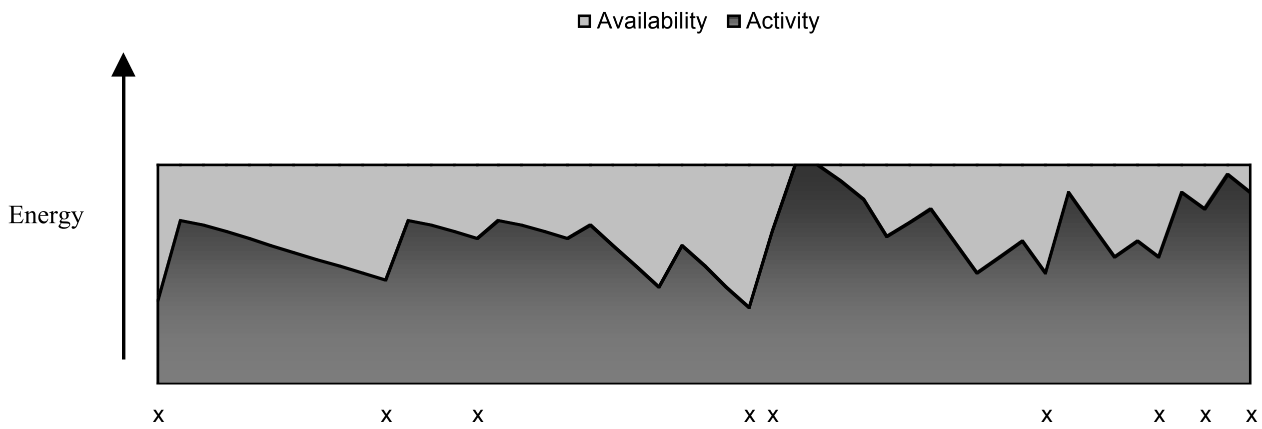



**Figure 7.6:** Sketch showing how resource availability remains uniform as resource activity fluctuates in response to nonmetric structure. 'x's represent nonmetrical pattern elements.

Uniformity of resource availability is not the only reason why prioritised integrative attending is problematic in nonmetrical contexts. Even if resource availability was forced to vary in accordance with metric frameworks generated proactively in the presence of nonmetrical patterns, the majority of nonmetrical events would occur in peripheral regions outside attentional foci. This would eventually lead to the adoption of a uniform availability profile (in a manner that is analagous to the 'learned helplessness' effects in animal learning – wherein an animal gives up trying to master an aversive situation when they have been taught that their behaviour does not control the environment, Seligman, 1972) (see Figure 7.7).

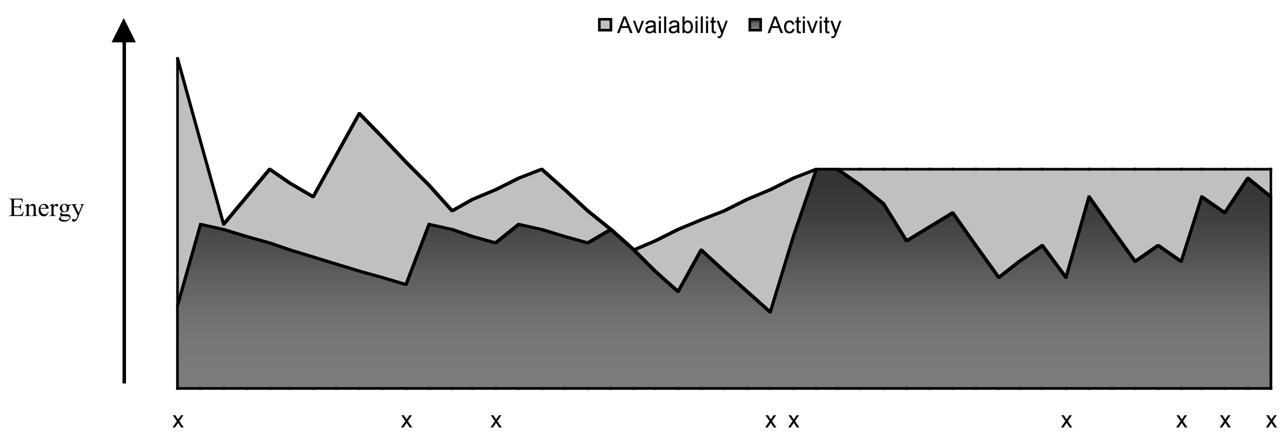



**Figure 7.7:** Sketch showing how resource availability mirrors metric structure initially, but eventually becomes uniform as resource activity fluctuates in response to nonmetric structure.

In any case, when attending to nonmetrical patterns, resource availability and resource activity are less likely to be correlated than when attending to metrical patterns. This independence becomes especially problematic in multipart contexts where prioritised integrative attending is required. This is because resource activity associated with attending to nonmetrical target integrant patterns frequently nears, or even meets, resource availability. Recovering from these frequent disturbances interferes with processing and leaves little scope for flexible attending to concurrent complementary integrant patterns.

#### *7.2.3.2.4 Graded resource activity*

Even though resource distribution is not conducive to prioritised integrative attending with nonmetrical target integrant patterns, complementary integrant patterns do not go totally unnoticed. Indeed, there was no evidence for floor effects in the nonmetrical conditions of the multipart experiments reported in Chapter 6. Residual resources for complementary integrant patterns (and other concurrent information) are permanently available, owing to the assumption that activity is distributed over attentional locales at a single timepoint in varying quantities. Thus, activity is graded along a continuum of concentration, anchored by focused and peripheral attention (see Figure 7.8). Activity is, therefore, not only focused in time, but also with regard to frequency regions and spatial location.

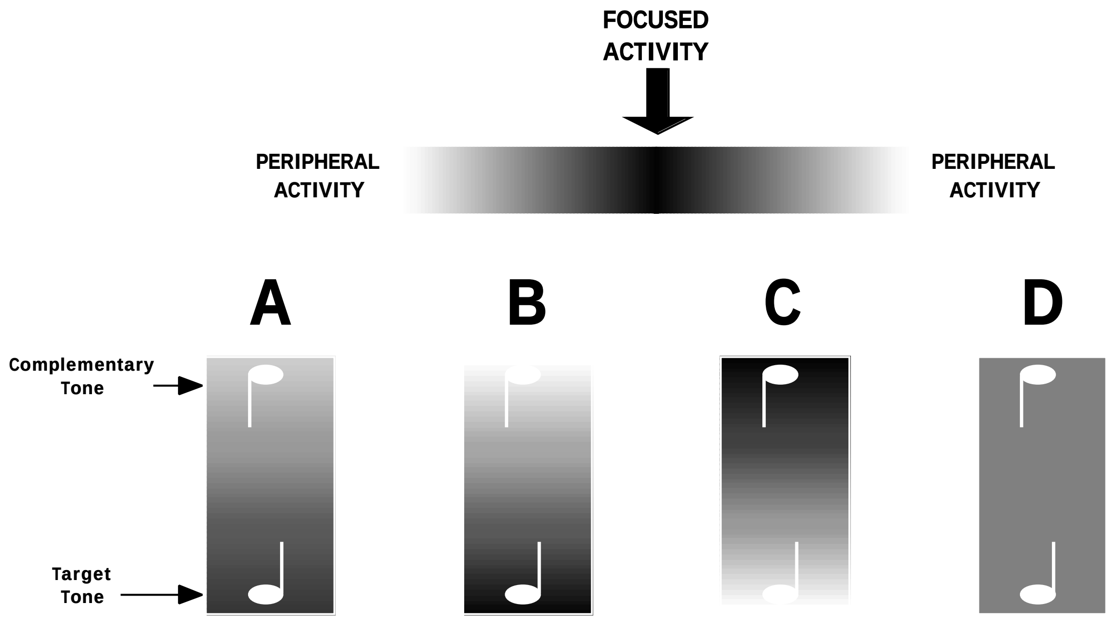



**Figure 7.8:** Graded resource activity with (A) moderate focus on target tone, (B) sharp focus on target, (C) sharp focus on complementary tone, and (D) even distribution between target and complementary tones.

The graded activity assumption – often articulated as some form of ‘gradient’ metaphor, wherein attention varies inversely with distance from a peak focal region – underlies many contemporary theories of attention (see Fernandez-Duque & Johnson, 1999). Here it is assumed that the sharpness of attentional focus influences the strength of peripheral attention: sharpening focus draws resources away from the periphery, thus diffusing attention (compare A with B in Figure 7.8). However, some activity always continues effortlessly at the periphery (e.g., monitoring processes that run automatically and may play a role in implicit learning and implicit memory). In a general sense, peripheral activity ‘protects’ performance on tasks that involve attention to stimuli that are not able to be focused upon due to concurrent task demands (Tsang, Veazques, & Vidulich, 1996).

The graded spread of activity over all available resources ensures that complementary integrant patterns receive some degree of processing, even in the worst case scenario – selective attending to nonmetrical target integrant patterns. However, whether trans-integrant grouping processes take place under such circumstances is questionable, as peripheral information generally receives less elaborate processing than target information (Broadbent, 1958; Craik & Lockhart, 1972; Moray, 1969; Pashler, 1998).

The graded activity assumption can be used to explain the effects of attending mode observed in the multipart experiments reported in Chapter 6. For example, in Multipart Experiment 2, recognition accuracy was better for target integrant patterns under selective attending conditions than under prioritised integrative attending conditions. Perhaps listeners were unable to focus activity sharply upon the target integrant pattern during prioritised integrative attending because complementary integrant patterns also require some degree of focused activity. It was also found in Multipart Experiment 2 that aggregate patterns were recognised more accurately under nonprioritised integrative attending conditions than under prioritised integrative attending conditions. The graded activity concept suggests that this might be because focusing resource activity upon the target integrant pattern during prioritised integrative attending draws resources away from the complementary integrant pattern, thus leading to relatively impoverished perception of the aggregate pattern structure.

The manner in which resource activity is graded may also be affected by musical skill. It was found in Multipart Experiment 2 that recognition accuracy for aggregate patterns was greater in musicians than nonmusicians. Perhaps musical skill increases the size of the region across which resource activity can remain focused, allowing the listener's attention to span target integrant and complementary patterns more comfortably.

#### *7.2.3.2.5 Other rhythmic phenomena*

So far, the ability of the two-factor account to deal with rhythmic phenomena such as the metrical/nonmetrical distinction and prioritised integrative attending in multipart rhythmic contexts has been described. In Chapter 1 (section 1.2.4.3), however, it was argued that models of rhythmic behaviour should be able to accommodate a wide variety of other rhythmic phenomena, such as polyrhythm, polymeter, mixed meter, complex meter, auditory streaming, and expressive timing. These phenomena need not be addressed here, as the emphasis of this dissertation is on multipart rhythmic behaviour generally, rather than how it is affected by these special devices. Nevertheless, to exemplify how the two-factor account extends to these situations, the case of polyrhythm shall be mentioned briefly.

Polyrhythm occurs when a pattern is comprised of two concurrent sequences that share the same underlying bar-level period, but differ in terms of beat period (see 1.2.2.4). It has been found that the polyrhythmic production is assisted by conceptualising the pattern as an integrated whole, rather than two separate streams (e.g., Deutsch, 1983). According to the two-factor theory, this strategy is optimal because (a) separate resource availability profiles (e.g., one per sequence) cannot coexist in an individual attender, and (b) commitment to a profile associated exclusively with one sequence would encounter interference by resource activity associated with the other sequence (unless the level of activity required is low, which may be the case for individuals with high expertise). Therefore, a combined resource availability profile is the most efficient solution.

Combined profiles are derived by summing the moment-by-moment maximum values from the profile associated with each sequence in a similar fashion to how the frequency waveform of complex sounds is generated by summing across separate sine wave components (see Luce, 1993; Moore, 1997). Such combined profiles have been used to model expectancy formation (Desain, 1992), and the activity of multiple oscillators underlying meter (Large & Kolen, 1994; Large & Jones, 1999). In the present conceptualisation, availability profiles are also 'averaged' by dividing the summed combination by the number of profile components (i.e., polyrhythmic or metric levels).

This transformation, which keeps the amplitude of the combined profile in check, is necessary due to the finite availability assumption: the same overall amount of resources are available regardless of how many levels of pulsation are generated. Panel A in Figure 7.9 shows a 3 x 4 polyrhythm, Panel B shows the resource availability and activity profiles associated with each separate stream in the polyrhythm, and Panel C shows the availability and activity profiles for both streams combined. More detailed discussion of the derivation of combined availability profiles will be not be undertaken here, and is postponed until the two-factor account is formalised in future work.[27]

[27] The rather crude procedure outlined here is intended more as a conceptual aid than as an accurate mathematical description of combined availability profiles.

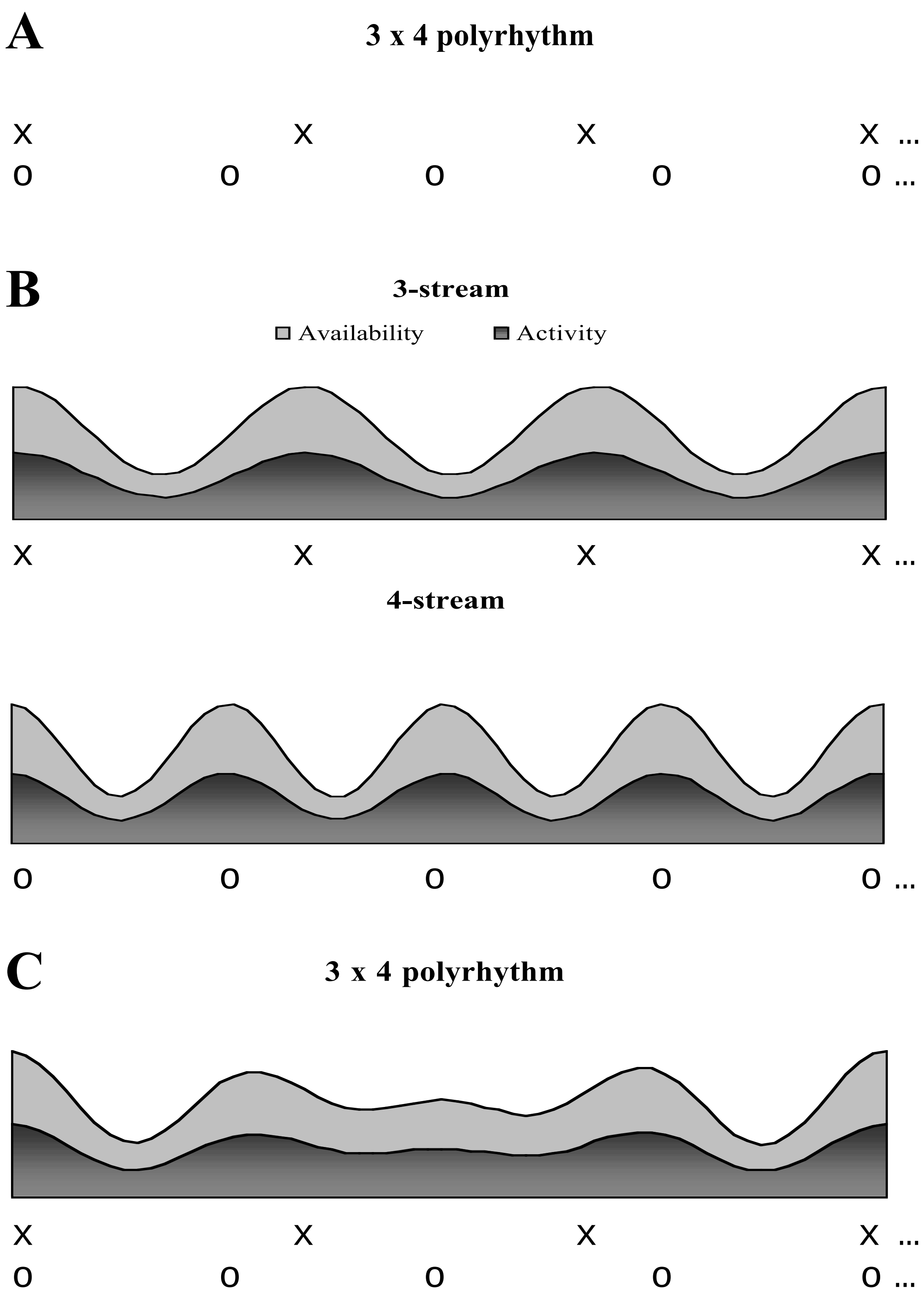



**Figure 7.9:** *Panel A* – a 3 x 4 polyrhythm; *Panel B* – resource availability and activity profiles for each separate polyrhythmic stream; *Panel C* – profiles for both streams combined.

##### *7.2.3.2.6 Summary of assumptions*

The main assumptions, or premises, of the two-factor account of attentional resource allocation are summarised in Table 7.1. This two-factor account can be used as the core of a broader theoretical account of attentional resource allocation in ensemble performance, which is outlined in the next section.

**Table 7.1:** Premises of the two-factor account of attentional resource allocation.

**Resource availability:**

(a) availability is finite at any given point in time

(b) availability fluctuates across timepoints in a manner that mirrors the profile of metric frameworks if an appropriate cognitive/motor schema is invoked

(c) availability is constant over time, or fluctuates randomly, in the absence of schema use or certain physiological change

**Resource activity:**

(d) activity is limited by availability

(e) the default pattern of activity mirrors the distribution of availability across time

(f) activity is regulated by a feedback mechanism that is sensitive to availability limits, and thus functions to ensure that activity remains within these limits – insofar as task priorities permit

(g) activity is distributed over attentional locales at a single timepoint in graded quantities ranging from focused to peripheral

(h) sharpening the focus of activity draws resources away from the periphery

(i) activity becomes focused, at frequency/space/time regions where target events occur, or where they are expected to occur

(j) sustained focused activity is effortful and fatiguing to resources, and leads to decreases in availability

(k) peripheral activity is effortless

### 7.2.4 Theory of Attentional Resource Allocation in Musical Ensemble Performance (ARAMEP)

The theory of Attentional Resource Allocation in Musical Ensemble Performance (ARAMEP) proposed here accounts for the conditions that affect resource availability and activity, and the factors that bring about these conditions, during prioritised integrative attending in multipart contexts. Three types of *performer/context state* – pertaining to the relationship between the individual performer and their surrounding musical context – are included in the theoretical framework: intrinsic cognitive-motivational, intrinsic executive, and extrinsic states (see Figure 7.10). Intrinsic states occur within the performer, and include the degree to which his or her perceptual, cognitive, and motor systems are prepared to deal with the multipart interaction at hand. Two varieties of intrinsic states are distinguished: cognitive-motivational and executive. *Intrinsic cognitive-motivational states* refer to high level cognitive phenomena such as performance goals, attentional sets, and motivational or emotional factors such as mood. *Intrinsic executive states*, on the other hand, give rise to strategies – such as performance plans and motor control processes (see 3.4.3.1.2) – for producing target behaviour. In contrast to intrinsic conditions, *extrinsic states* occur in the performer's external environment, which comprises the ensemble sound (i.e., the music itself), physical surroundings, and ambient social context.

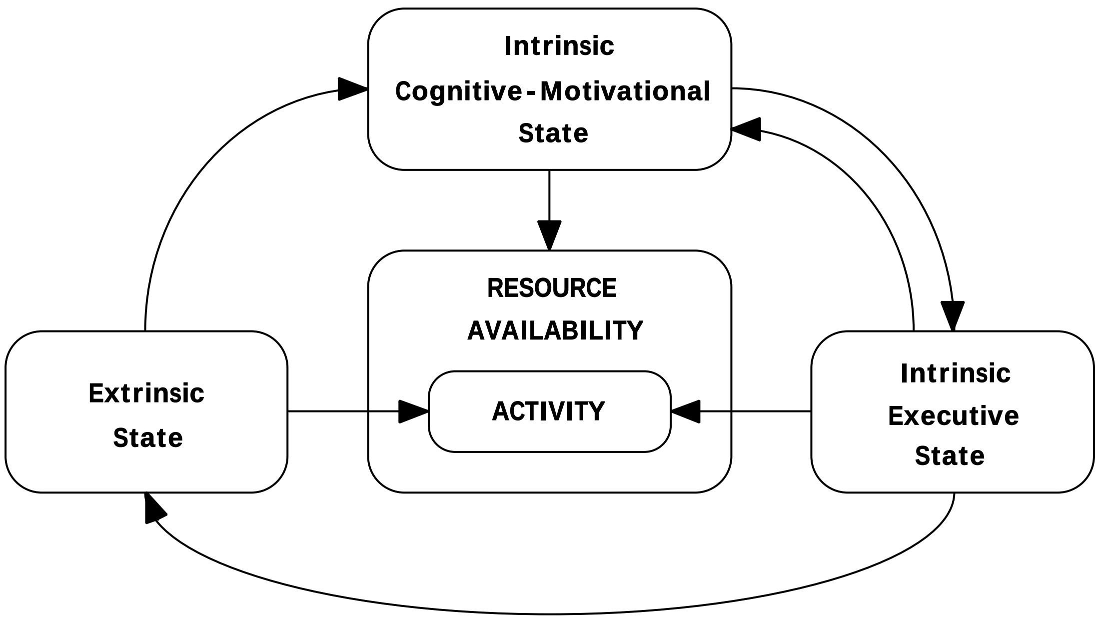



**Figure 7.10:** Interaction between performer/context states and resource availability and resource activity in ARAMEP.

Causal links are assumed to exist between the three performer/context states. Extrinsic state affects intrinsic cognitive-motivational state (e.g., ensemble sound structure determines which schemas are invoked, and social context influences anxiety level); intrinsic cognitive-motivational state modulates intrinsic executive state (e.g., anxiety affects motor control); intrinsic executive state influences extrinsic state (e.g., motor control affects ensemble sound). A feedback link from intrinsic executive system to the intrinsic cognitive-motivational system is also assumed to exist for the endogenous regulation of motor control. Error correction based on physiological feedback, rather than external acoustic sources (see Pressing, 1998, 1999), occurs via this feedback link.

Performer/context states (intrinsic cognitive-motivational, intrinsic executive, and extrinsic) are linked systematically to the core attentional resource control processes (resource availability and resource activity). The intrinsic cognitive-motivational system modulates both resource availability and resource activity. For example, schemas such as metric frameworks, and mood-related factors such as anxiety, determine the profile of both resource availability and activity across time. In contrast, extrinsic states, and intrinsic executive states, have a direct influence only upon resource activity. Events comprising the ensemble sound and the surrounding environmental context, and motor control processes, guide the focusing of attention but do not affect availability directly (they may, nevertheless, influence availability indirectly through their effects upon the intrinsic cognitive-motivational system). Hence, the intrinsic cognitive-motivational system takes pride of place amongst performer/context states.

Two broad varieties of factors are postulated to affect performer/context state: musical factors and extramusical factors (see Figure 7.11). Musical factors include elements of the ensemble sound (rhythm, texture, tonality, melodic contour, pitch interval size, and balance, or the relative loudness of parts), as well as schemas that guide the performer's processing and representation of the music. Extramusical factors include characteristics of the performance environment (acoustic conditions, lighting, background noise), the performer's level of technical mastery on their instrument (purely in terms of motor control), and the performer's psychophysiological state during performance (level of anxiety, arousal, and motivation). The EPQ findings reported in Chapter 2 support the role of these factors in ensemble performance.

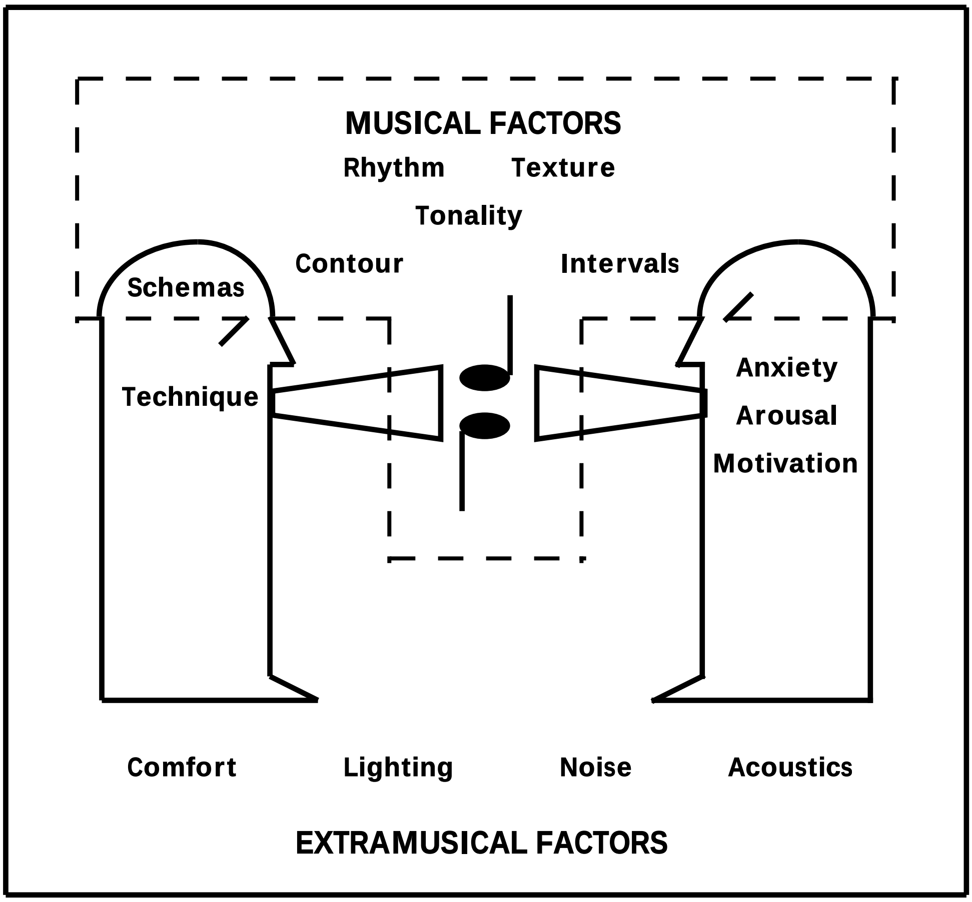



**Figure 7.11:** Musical and extramusical factors in ARAMEP.

Table 7.2 shows specific musical and extramusical factors that are instrumental in defining each performer/context state. Extrinsic states are influenced directly by musical factors relating to elements of the ensemble sound and extramusical factors such as characteristics of the performance environment. Intrinsic cognitive-motivational states incorporate musical factors including certain types of schema (e.g., metric frameworks, abstract knowledge of tonality, and performance goals), and are modulated directly by the rhythmic structure of the music (in addition to being influenced, through their link with extrinsic conditions, by the interaction of other musical elements). Clearly, these musical schemes are moulded by musical experience. Intrinsic cognitive-motivational states also incorporate the extramusical factors anxiety, arousal, and motivation. Intrinsic executive conditions are defined jointly by the performer's technical mastery and the schemas that guide their motor actions (e.g., performance plans). Like cognitive-motivational state, executive state is affected by musical experience.

**Table 7.2:** Relationship between performer/context state and musical and extramusical factors.

| Performer/Context States | Musical Factors | Extramusical Factors |
|---|---|---|
| ***Intrinsic Cognitive-Motivational*** | · Musical schemas:<br>→ metric frameworks<br>→ tonality<br>· Performance goals | · Anxiety<br>· Arousal<br>· Motivation |
| ***Intrinsic Executive*** | · Performance plans | · Instrumental technique |
| ***Extrinsic*** | · Ensemble sound:<br>→ rhythm<br>→ texture<br>→ tonality<br>→ melodic contour<br>→ pitch-interval size | · Environmental setting:<br>→ acoustic conditions<br>→ lighting<br>→ background noise<br>→ comfort |

The way in which musical and extramusical factors relate to the performer/context states has implications for how these factors affect attentional control processes. Specifically, the temporal profile of resource activity is determined by the full range of musical and extramusical factors (each to varying degrees), whereas the timecourse of resource availability is determined exclusively by schematic musical factors, and the physiological extramusical factors - anxiety, arousal, and motivation. It was Kahneman (1973) who originally proposed that the amount of available attentional resources varies with arousal. His conception of the relationship between arousal and performance is consistent with the ubiquitous Yerkes-Dodson law (Yerkes & Dodson, 1908): availability is optimal at intermediate levels of arousal, but limited at extremely high or low arousal. Following from assumptions c and j of the two-factor account of resources (see Table 7.1), activity is not elevated sufficiently at low levels of arousal to necessitate increased availability, whereas the heightened activity associated with high arousal is fatiguing to resources. However, it should be pointed out that the idea of systematic fluctuations in resource availability along the timescale where meter resides is not common in traditional theories of attentional resource allocation. This proposal is unique to ARAMEP, and the two-factor account of attentional resource allocation in particular.

In ARAMEP it is assumed that availability is influenced similarly by anxiety and motivation, either directly, or through their effects upon the physiological mechanisms that control arousal. Support for the interrelatedness of arousal, anxiety, and motivation comes from psychophysiological studies (e.g., Hockey, Gaillard, & Coles, 1986).

The relationship between resource activity and availability, on the one hand, and schemas such as meter, on the other, deserves special mention, given the themes of this dissertation. The central claim is that metric pulsations are in fact fluctuations in resource availability (see 7.2.3.2.2). In proactive metric framework generation, a particular pattern of these fluctuations is invoked through enlistment of a metric schema, equivalent to the expectancy schemes that characterise dynamic attending theory (Jones, 1982, 1990). Here it is claimed that a particular schema, *and* corresponding resource availability profile, is deliberately invoked and used to guide resource activity.

Reactive metric framework generation is achieved via a less direct path. External rhythmic structures command a certain pattern of resource activity. This activity profile, if it contains periodicities, eventually finds resonance with a metric schema (c.f. Large & Kolen, 1994; Large & Jones, 1999), and hence automatically inspires a matching resource availability profile. Another way to view the relationship between rhythm and resources is related to the figural and metric aspects of rhythm (Bamberger, 1991; Essens, 1995; see 3.4.3.2.2): the figural aspect commands resource activity, whereas the metric aspect is linked to availability. The primary benefit of binding meter to resource availability is that it provides a mechanism, which has been lacking in other theories of rhythm, for understanding the resource allocation processes underlying prioritised integrative attending in multipart contexts. To revisit the analogy made in section 3.4.3.4, meter controls resource allocation like an autopilot system controls an aircraft.

As a theory of multiple task behaviour, ARAMEP is relatively limited in scope. Task structure, demands, and goals are highly constrained. Task structure is dictated wholly by the multipart musical structure guiding the ensemble performance in question. In particular, task structure is conceived in terms of the complexity of individual instrumental parts and the way in which they mesh. Task demands are then set by the interaction of this structure with task goals, which relate mainly to prioritised integrative attending. Therefore, demands become higher with increasing structural complexity, assuming that task priorities remain constant.

### 7.2.5 ARAMEP compared to other multiple task theories

The specificity of ARAMEP stands in contrast to more general theories of multiple task behaviour such as the state-of-the-art Executive-Process Interactive Control (EPIC) theory formulated by Meyer and Kieras (1995, 1997a, 1997b, 1999). EPIC is concerned primarily with 'executive processes' for controlling dual task performance by supervising flexible schedules that coordinate progress on each task. To facilitate these control schedules, EPIC's architecture is comprised of several modules that interact heterarchically with one another. These include: (a) a *declarative long-term memory store* where propositional (i.e., verbally-based) knowledge about task goals and priorities is represented, (b) a *procedural memory store* containing production rules for performing each task, (c) a *cognitive processor* consisting of a *declarative working memory store* (where external stimuli, task goals, and potential responses are represented symbolically) and a *production rule interpreter* (which is responsible for applying production rules to the contents of working memory via series of if-then statements), (d) auditory, visual, and tactile *perceptual processors*, and (e) vocal and manual *motor processors*.

Meyer and Kieras (1997b, p. 750) describe how the cognitive, perceptual, and motor processors interact: "perceptual processors deposit symbolic stimulus codes in the declarative working memory of EPIC's cognitive processor. The cognitive processor maintains the contents of working memory, executes procedures for performing particular tasks, and instructs the motor processors by transmitting symbolic response codes to them". Thus, the cognitive processor, or its production rule interpreter in particular, is responsible for attentional resource allocation.

EPIC's cognitive processor operates through a series of continuous cycles. During each cycle, the contents of working memory are updated, production rules are evaluated against the updated contents, and then actions are executed for each rule whose conditions are satisfied. The duration of each cycle is fixed at 50 ms, irrespective of the number of production rules involved or the temporal properties of the external stimulus (Meyer & Kieras, 1995, 1997a, 1997b). This implies that attention per se (a) is unaffected by task complexity and (b) does not become synchronised with external events, at least in elementary dual task situations in which EPIC has been evaluated.

The immunity of attentional processes to the effects of task complexity rests on the assumption that EPIC's cognitive processor has no a priori capacity limits – although Meyer and Kieras (1996, 1997a) acknowledge that such 'central' limits may need to be incorporated when EPIC is applied to complex multiple task situations. In existing versions of EPIC, however, decrements in multiple task performance are attributed exclusively to limited sensory and motor mechanisms, and the effectiveness of control strategies used to overcome these 'peripheral' limits. This does not yield a sufficient explanation of the results of the current Multipart Experiment 1 (Efficiency at encoding), wherein attentional flexibility was affected markedly in a task where complexity was essentially independent of sensory and motor demands. Moreover, the general lack of synchrony between cognitive processes and external stimuli in EPIC, along with its 'absolute' conception of time (with processing cycles fixed at 50 ms) and algorithmic rule-based approach, are not conducive to explaining the dynamic attentional phenomena demonstrated in the current multipart experiments.

Nevertheless, EPIC is impressive in its ability to embrace a multitude of other task structures, demands, and goals, and some aspects of its design can be used to extend ARAMEP and thereby increase its generality. For example, EPIC's memory modules, executive supervisory control system, and sensory and motor processes could reside comfortably at the level where intrinsic cognitive-motivational and intrinsic executive states are specified in ARAMEP (see Figure 7.12). The intrinsic cognitive-motivational system might include a supervisory control mechanism (see Logan, 1985; Neisser, 1967; Norman & Shallice, 1986, 1998; Shallice & Burgess, 1993) that has bidirectional links with both declarative long-term memory (see Anderson, 1995; Cohen, Poldrack, & Eichenbaum, 1997; Parkin, 1997) and working memory (see Baddeley, 1986, 1998; Miyake & Shah, 1999). Working memory, in turn, might be linked to sensory mechanisms (see Gibson, Hagan, & Haber, 1992; Llinas & Churchland, 1996), as in EPIC. ARAMEP's intrinsic executive system might include procedural memory (see Anderson, 1995; Cohen, Poldrack, & Eichenbaum, 1997; Parkin, 1997) and motor control mechanisms (see Heuer & Keele, 1996; Jeannerod, 1998; Rosenbaum, 1991), which are both linked (like the cognitive-motivational components) to the supervisory control mechanism. Links also exist to extrinsic states including environmental setting and ensemble sound.

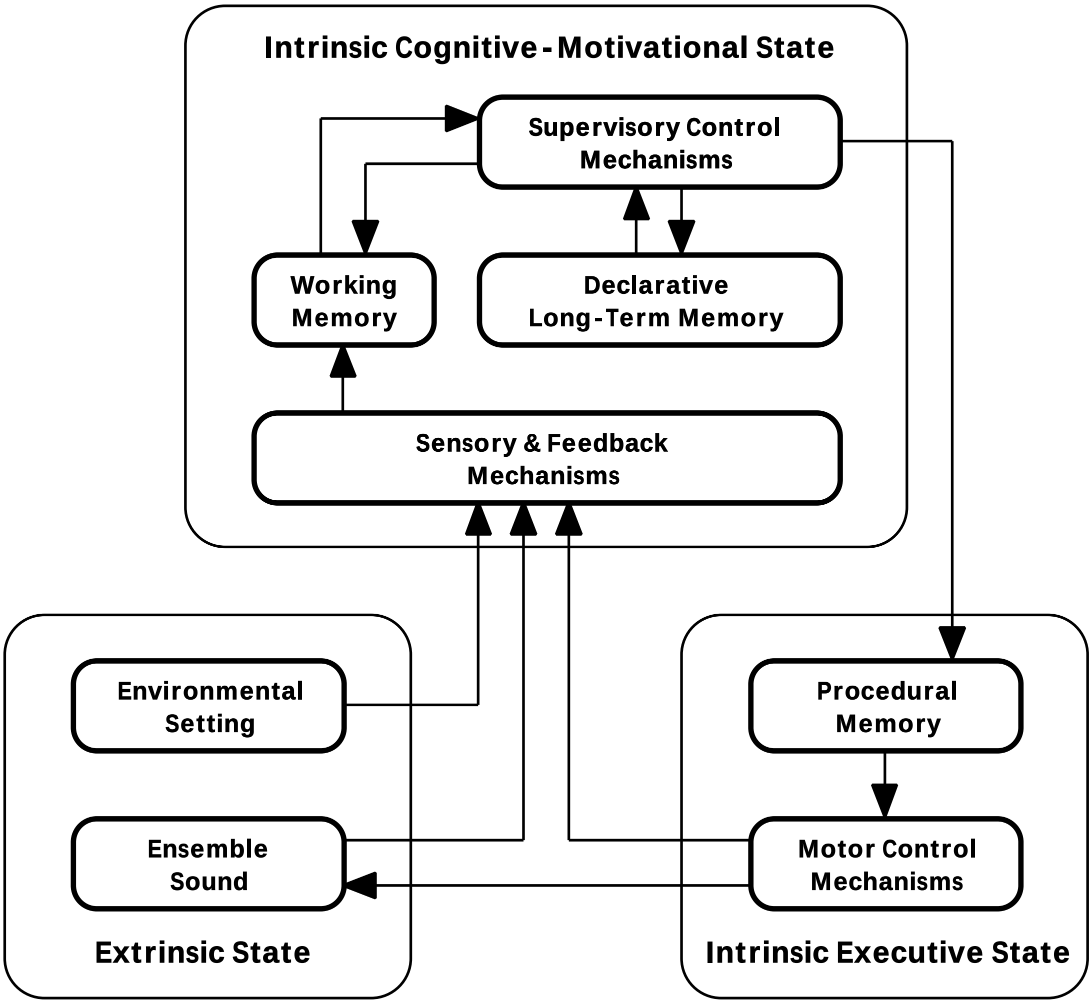



**Figure 7.12:** Memory modules and control mechanisms in ARAMEP (inspired in part by Meyer & Kieras, 1997a, 1997b).

It should be noted that ARAMEP is presently not strongly committed to these various modules and mechanisms, especially the distinct memory stores, as the notion of memory 'storage' in general is controversial (Crowder, 1993a, 1993b; Kolers & Roediger, 1984). Nevertheless, it should be acknowledged that the concept of storage is useful insofar as it allows persisting memory representations (e.g., performance goals – in declarative long-term memory – and performance plans – in procedural memory) to be accounted for by the theory.

One significant feature of EPIC is its predictive power. As a computational theory, EPIC has been used as a basis for formulating quantitative models that predict performance (mainly in terms of reaction time) on multiple-tasks in human-computer interaction and aviation (see Meyer & Kieras, 1997b, 1999). At present, ARAMEP is only a qualitative framework, although there are plans to quantify its parameters in future research using dynamical systems theory (e.g., Abraham, Abraham, Shaw, & Garfinkel, 1990; Palm, 1983; Port & Van Gelder, 1995) or related approaches to modelling such as Pressing's (1999) referential behaviour theory. Nevertheless, even currently it can be used to generate specific predictions about prioritised integrative attending.

## 7.2.6 Testing ARAMEP

### 7.2.6.1 Predictions

ARAMEP embodies predictions about the effects of the musical and extramusical factors, listed earlier in Table 7.2, upon attentional resource allocation during prioritised integrative attending in multipart musical contexts. The factors that interfere with prioritised integrative attending, and the basic resource allocation mechanisms through which they accomplish this, are summarised in Table 7.3. This summary identifies how each factor relates to different sources of interference. Thus, interference may be caused by (a) decreasing resource availability (e.g., brought about by anxiety and arousal), (b) increasing resource activity (e.g., related to textural and pitch-based complexity), or (c) by decoupling availability and activity (e.g., through rhythmic complexity). Complex interactive effects may also arise through combinations of musical and extramusical factors.

ARAMEP was formulated with ensemble performance in mind, and therefore it should ideally be evaluated in production-based tasks such as the simulated ensemble performance paradigm employed in Multipart Experiment 3 (Rhythmic canon). For example, a musically skilled participant (not necessarily a percussionist) could be asked to perform in the context of either a real, or simulated ensemble in which the complexity of individual parts, and their interrelationship, is manipulated systematically. Success at prioritised integrative attending could be assessed by measures including the participant's (a) production accuracy, (b) ability to detect target events in another part of the ensemble, or (c) memory for the aggregate ensemble sound. However, perhaps this version of the simulated ensemble performance paradigm is not optimal because it relies upon the participant to produce their part accurately – otherwise the relationship between parts is disrupted. Therefore, it might be preferable to begin testing ARAMEP with listening-based experiments where it is possible to exercise tighter control over the relationship between parts. Some examples of experimental designs for testing the hypothesised effects of rhythmic and pitch-based complexity are now outlined.

**Table 7.3:** Summary of ARAMEP's predictions about the factors that intefere with prioritised integrative attending.

| Factors | Effects |
|---|---|
| • High multipart rhythmic complexity | → Decoupling of availability and activity |
| • Dense texture (i.e., large number of integrant patterns) | → Increased activity without corresponding increase in availability |
| • Poor balance | → Narrowing focus of activity to monitor softer parts |
| • Large pitch-interval size (leaps rather than steps) in own part | → Increased activity to overcome technical hurdles |
| • Large pitch-interval size in other parts | → Increased activity (intensive shifting in focus) to accommodate greater distances in cognitive pitch space |
| • Jagged (as opposed to smooth) melodic contour in own part | → Increased activity to overcome technical hurdles |
| • Jagged melodic contour in other parts | → Increased activity to recover from interruptions to attentional trajectories as melodic motion changes direction |
| • Unfamiliar or unstable tonality | → Increased activity to generate local expectancies online, and/or to recover from expectancy violations |
| • Uncomfortable surrounds: | |
| - poor acoustics | → Increased activity to overcome difficulty hearing |
| - distractions | → Increased activity causing interference |
| • Extreme (high or low) levels of anxiety, arousal, and motivation | → Reduced availability |
| • Inadequate technical mastery | → Increased activity to overcome technical difficulties |
| • Impoverished cognitive/motor schemas (e.g., due to lacking musical experience) | → Increased activity to gather missing information, or to recover from expectancy violations |
| | → Less than optimal availability profile |

#### 7.2.6.2 Rhythmic timecourse of prioritised integrative attending

A listening paradigm similar to that used in Multipart Experiment 1 (Efficiency at encoding) would be suitable for investigating the effects of rhythmic complexity upon resource availability and resource activity. Listeners could be asked to memorise target integrant (metrical or nonmetrical) and aggregate aspects of a multipart exposure item simultaneously in each experimental trial. Then, on half the trials (selected randomly), an integrant recognition memory test item would be presented following the exposure item, and on the other half, an aggregate test item would be presented. So far this procedure is identical to that employed in Multipart Experiment 1. The point of departure from the original design is to supplement this with a detection task. In order to examine how ability to engage in prioritised integrative attending varies as a function of metric location, a spectrally altered tone (see Klein & Jones, 1996) would occur within the complementary integrant pattern in half the trials during pattern exposure. This deviant probe tone would be placed at locations that are graded in terms of metric strength. Prior to each memory test item, listeners would be required to report on whether a deviant tone was present or absent in the preceding exposure item.

If resource availability is increased at strong metric locations to compensate for increases in resource activity (due to a higher concentration of elements in metrical target integrant patterns at these locations), then deviant detection should be most accurate in the vicinity of strong metric regions. Comparison with performance in nonprioritised integrative attending conditions (where availability is not as much of an issue because less flexibility is required), would reveal whether any observed effects are due simply to increased activity at strong locales. If availability does not fluctuate, then performance should be worse with prioritised integrative attending than nonprioritised integrative attending simply due to higher levels of activity in the former. However, if target detection is equally accurate under prioritised integrative attending and nonprioritised integrative attending, then an explanation based solely upon activity could be deemed insufficient.

#### 7.2.6.3 Pitch-based effects: Pitch interval size and melodic contour

Pitch interval size and melodic contour both contribute to pitch-based complexity (see 2.3.4.1.2). To study the effects of pitch interval size and melodic contour upon prioritised integrative attending, a simple 2 x 2 repeated measures design could be used, in conjunction with the 'prioritised integrative attending at encoding' multipart listening paradigm. However, as a change to the original design, metricality of the target integrant and aggregate patterns would be held constant to isolate the effects of pitch-based complexity. Thus, target integrant patterns in multipart exposure items would consist of metrical melodies that vary in a 2 x 2 fashion in terms of pitch interval size (steps or leaps) and contour (smooth or jagged). In each experimental trial, listeners would be instructed to focus on, and memorise, only the rhythm of the target integrant pattern (i.e., ignore pitch changes) and the aggregate pattern (complementary integrant patterns would be presented by a nonpitch percussion sound). Then memory would be tested for either the integrant or aggregate rhythm. If prioritised integrative attending is affected by pitch-based complexity (through increased resource activity), then aggregate pattern recognition should be worst in the leaps/jagged condition and best in the steps/smooth condition, with intermediate performance in steps/jagged and leaps/smooth conditions.

#### 7.2.6.4 Interactive effects of rhythm and pitch

The procedures described above in sections 7.2.6.2 and 7.2.6.3 could be combined to test the interactive effects of rhythmic and pitch-based complexity upon prioritised integrative attending. The implications of these interactive effects for attentional flexibility in general (i.e., not specifically with regard to prioritised integrative attending) are emphasied in the dynamic attending approach (Jones, 1976). According to this approach, constraints related to the serial integration region (SIR) determine the degree to which pitch-time (i.e., melodic) structure is compatible with coherent, and hence efficient attentional trajectories (see 1.2.3.2.2). Jones (1992, p. 98) claims that the size of the SIR is "proportional to the event time hierarchy that currently controls attending", and that "the SIR is larger for future-oriented attending than for analytic attending". This implies that the attender is able to cast attention over larger pitch-time areas when attending is guided by metric frameworks than when it is not. The size of the area in pitch-time space covered by attention can be taken as an indicator of attentional flexibility.

Jones (1976, p. 346) proposes that when an attender is confronted by a complex sequence (e.g., a nonmetrical target integrant pattern), "Energy is drawn from other locales to the one associated with the difficult sequence so that, effectively, SIRs at other locales narrow…". This can be taken to suggest that, in multipart contexts, attending to a nonmetrical target integrant pattern will restrict the SIR related to complementary integrant patterns. In the terminology of the two-factor account of resources at the core of ARAMEP, this means that attentional activity becomes focused on the target integrant pattern, leaving its complementary counterpart in the periphery. Therefore, the attender 'misses' a lot of information about the structure of complementary integrant patterns (especially as resource availabiltiy is low), and, hence, has little chance of successfully integrating it with the target integrant pattern (i.e., trans-integrant grouping). This account leads to several predictions about the interaction of rhythm and pitch-based complexity during prioritised integrative attending.

Consider that the experimental designs in sections 7.2.6.3 and 7.2.6.4 are combined without the intermediate (step/jagged and leap/smooth) pitch-based complexity conditions. A 2 x 2 repeated measures design would result, with variables rhythmic complexity (metrical or nonmetrical) and pitch-based complexity (step/smooth – 'lyrical' – or leap/jagged – 'nonlyrical'). Clearly, ARAMEP predicts that prioritised integrative attending performance (and detection of deviant tones, if this measure is employed) should be best in the metrical/lyrical condition and worst in the nonmetrical/nonlyrical condition. Furthermore, given the relationship between meter and resource availability in ARAMEP, the effects of rhythmic complexity should be dominant. Therefore, performance should be better in the metrical/nonlyrical condition than in the nonmetrical/lyrical condition.

#### 7.2.6.5 Neurophysiological approaches

Neurophysiological techniques may also be useful in testing some assumptions about certain aspects of ARAMEP. Indeed, many researchers have recommended the use of physiological measures to study resource allocation in other forms of multiple task behaviour (see Meyer & Kieras, 1997a, 1997b; Wickens, 1984). Techniques with fine temporal resolution may be particularly useful for demonstrating resource plasticity. For example, the SSVEP study by Harris et al. (1998) (see 7.2.2) provides tentative evidence for the uneven temporal distribution of resources during auditory pattern processing.

Harris et al. (1998) measured activity in the left dorsolateral prefrontal cortex (which plays a role in working memory and the detection of change in the auditory environment) whilst participants listened to sequences consisting of groups of short tones punctuated by irregularly occurring longer tones. They found that cortical activity decreased following the first short tone after each long tone. Relatively long tones, by virtue of their salience, often serve as cues to metrical accents (see 1.2.1.3). Therefore, although the sequences used by Harris et al. (1998) were nonmetrical, the observed drop in processing at a fixed interval after long tones may be viewed as a response to cues that commonly signal meter. In this interpretation, the results of the Harris et al. study are consistent with the proposal that metric structure plays a role in modulating attentional resources. Combining such techniques with manipulations of workload and arousal or motivation should allow the relationship between resource availability and resource activity to be examined.

### 7.2.7 Further implications of ARAMEP and current empirical findings

ARAMEP goes well beyond the empirical findings reported in this dissertation. It is offered here mainly as a heuristic for studying further the attentional processes involved in ensemble performance. It is thus hoped that ARAMEP will engender greater appreciation of the complexity of ensemble performance, and demonstrate how the special skills required in ensembles transcend the skills commonly identified in music education to comprise a performer's general musical ability. Technical competence as an instrumentalist, accurate perceptual-motor skills, and artistry as an interpreter of music are necessary, but by no means sufficient, for excellence as an ensemble performer. Specific prioritised integrative attending skills such as tracking, trans-integrant grouping, and interdependent integrant/aggregate memory encoding are fundamental to ensemble cohesion and coherence. The nature of development of expertise in these skills is a topic ripe for investigation. One issue that is particularly tempting relates to whether prioritised integrative attending, which so far has been characterised as a dual task, may become a single task with high levels of expertise.

Under the rubric of 'task compatibility', Wickens (1991) describes how dual task performance is facilitated when the processing routines associated with each task are similar, and thus allow "an integration of the two task elements into one" (p. 3). Furthermore, the integration of task elements is often considered to be an index of skilled performance (Cheng, 1985; Wickens, 1989). This raises a question about performance in the current Multipart Experiments. Listeners in Multipart Experiment 1 (Efficiency at encoding) were expected to form separate (i.e., dual), yet interdependent, memory representations for the integrant and aggregate aspects of each multipart exposure pattern.

However, it is possible that they went about the task by memorising only the aggregate aspect (assigning different verbal labels to elements from target and complementary integrant streams, e.g., “du” and “pa”, see Figure 7.13), and then extracted the target integrant only when required during integrant test trials (i.e., by retrieving the “du” sequence). Thus, the memorisation phase may have been treated as a single task.

**Original multipart pattern:**

```
x-----------x---x--------------xx-------x---x-x-x
------o-o-o---o------ooooooo-oo-----o--o---------
```

**Aggregate representation:**

```
d-----p-p-p-d-p-d----ppppppp-ppdd---p--pd---d-d-d
```

**Figure 7.13:** Aggregate respresentation of multipart pattern with verbal labels distinguishing target and complementary tones (*d* = ‘du’ for target tone x, p = ‘pa’ for complementary tone o).

Although possible, it seems unlikely that this strategy was employed for two reasons: (a) the single task strategy would differ from nonprioritised integrative attending only on the basis of how verbal labels are assigned to each stream, yet in Multipart Experiment 1 there were marked differences in performance between prioritised and nonprioritised integrative attending conditions; (b) the results in Multipart Experiment 1 were qualitatively similar to those of Multipart Experiment 3 (Rhythmic canon), where dual task demands were unavoidable (i.e., aggregate memorisation was accompanied by integrant production, each of which may be seen to tap partially different resource pools, see Wickens, 1984). Ultimately, however, this is an issue that requires empirical resolution.

#### 7.2.7.1 Timesharing strategies: Switching versus parallel processing

An issue related to the dual task/single task distinction is the type of strategy used to share limited resource availability between target and complementary integrant streams. Barber (1988) identifies switching and parallel strategies as distinct styles of timesharing in dual task behaviour (also see Moray, 1969; Tsang et al., 1995; Wickens, 1991). Switching involves allocating resources alternately to each component task in a serial fashion. On the other hand, parallel strategies involve performing each component task simultaneously and continuously. Switching implies effortful processing to the extent that resources are allocated consciously, whereas parallel processing seems more likely to proceed automatically. In the language of the two-factor theory proposed earlier in this chapter, switching involves alternating the highly resolved focus of resource activity between elements belonging to target and complementary integrant patterns (compare B with C in Figure 7.8). By contrast, in parallel processing, resource activity is more diffuse and less resolved (see Figure 7.8 D). Switching should allow more detailed information to be picked up due to greater resolution in activity focus.

In multipart musical textures, the use of a switching strategy might involve shifting attention from target to complementary integrant patterns in an attempt to form interdependent representations of target integrant and aggregate pattern structure. A parallel processing strategy, on the other hand, would involve attending simultaneously and continuously to target and complementary integrant patterns. Of course, a higher proportion of resources would be devoted to processing target, than complementary, integrant patterns when engaged in prioritised integrative attending. There are conflicting views on whether attending to multipart musical textures entails switching or parallel processing.

Auditory streaming is one multipart domain where there is some controversy about switching versus parallel processing. Jones (1976, p. 343) claims that high and low streamed sequences are attended in parallel: "Perceptually, the result is not a serial concept but a parallel one that corresponds to figure-ground percepts". This claim follows from her proposal that parallel processing occurs when dimensional changes (rate of pitch change) exceed those that can be accommodated by the SIR. On the other hand, Michon and Jackson (1984, p. 309) argue that the perception of streamed sequences involves switching:

> "Time being notoriously one-dimensional we can cope with certain complexities only successively, at least in the deliberate mode of information processing. The way of coping with this difficulty is to perceptually split what is going on in a meaningfully patterned 'objectified' foreground, pushing all else into the background. A seeming simultaneity may then be maintained by quick alternation between foreground and background. This can be achieved only if there are indeed several concurrent patterns of information. This phenomenon has been studied extensively in auditory perception, where it is known as streaming".

The discrepancy between Jones' (1976) and Michon and Jackson's (1984) interpretations of streaming effects may stem from several possible sources. First, it may simply reflect idiosyncratic usage of language and metaphor to describe perceptual and cognitive processes (e.g., they may be viewing these processes from different levels of abstraction). Second, the discrepant interpretations may represent a theoretical dispute that awaits resolution on empirical grounds (e.g., whether streaming is a consequence of automatic or effortful processes). Finally, such discrepancies may suggest that similar behavioural outcomes are the result of different underlying processes. This final possibility might apply to prioritised integrative attending in multipart rhythmic textures.

It may be the case that prioritised integrative attending is attainable through the use of either switching or parallel processing, or even by the combined use of these strategies throughout a multipart interaction. Individuals may arrive at an interaction with several potential strategies at their disposal and employ them according to situational demands. Factors such as pattern complexity, the attender's skill, tempo, and texture may influence which strategy is adopted. Leman (1995, p. 61) comments anecdotally on the influence of musical texture on the attentional strategies employed by listeners:

> "For centuries, composers have explored the idea that vertical (or harmonic) writing compels listeners to adopt a listening strategy that favours the fusion of tones, while a polyphonic setting, on the other hand, is more oriented towards the analytic abilities of the human auditory system. By using transitions from harmonic to polyphonic writing, or ambiguous settings, interesting fluctuations occur. What is first heard globally, can later be heard analytically and vice versa. Listeners may even try to concentrate on one of these aspects and control perception actively".

Although Leman's statement does not explicitly distinguish between parallel and switching strategies, it does imply such a distinction, where "fusing of tones" results from a parallel strategy, and the "analytic abilities" refer to attentional switching.

#### 7.2.7.2 Distinguishing switching and parallel processing experimentally: Tempo effects

The switching versus parallel processing question might be resolved by examining the effect of tempo upon ability to engage in prioritised integrative attending. If switching is used, then prioritised integrative attending should be better at slow tempi than at fast tempi simply because there is more time to shift attentional focus between target and complementary streams at slow presentation rates. However, if parallel processing is used, then prioritised integrative attending should either remain unaffected by tempo, or possibly become more difficult as tempo decreases due to increasing working memory load. These hypotheses were investigated by conducting post-hoc analyses examining the effects of tempo (slow; medium; fast) upon prioritised integrative attending (indexed by both integrant and aggregate recognition accuracy) in Multipart Experiment 1 (Efficiency at encoding). The results of these analyses (see Appendices 7.1 & 7.2) should be taken as only tentative because presentation rate was not designed to be an independent variable in the experiment, and varied randomly (see 4.4.4.3.1). Therefore, each different combination of pattern type and presentation rate had a different number of data points, and not all participants received each pattern x rate combination. Nevertheless, some interesting trends emerged.

The results for target *integrant* patterns indicate differential effects of tempo for musicans and nonmusicians. As indexed by target minus distracter test item scores, musicians recognised target integrant patterns most accurately when tempo was slow, whereas nonmusicans performed best when tempo was fast (see Figure 7.14). This suggests that musical skill may have affected choice of timesharing strategy: musicians appear to have been using a switching strategy, while nonmusicians appear to employ parallel processing. Perhaps switching, although relatively active and intensive, was the most effective strategy for segregating the target integrant pattern. It is interesting to note that, according to the EPQ findings, individuals with less musical experience (amateur orchestral musicians) were more likely than their more experienced counterparts (professionals) to report that prioritised integrative attending proceeds automatically, which is consistent with a less intensive, more passive parallel processing strategy.

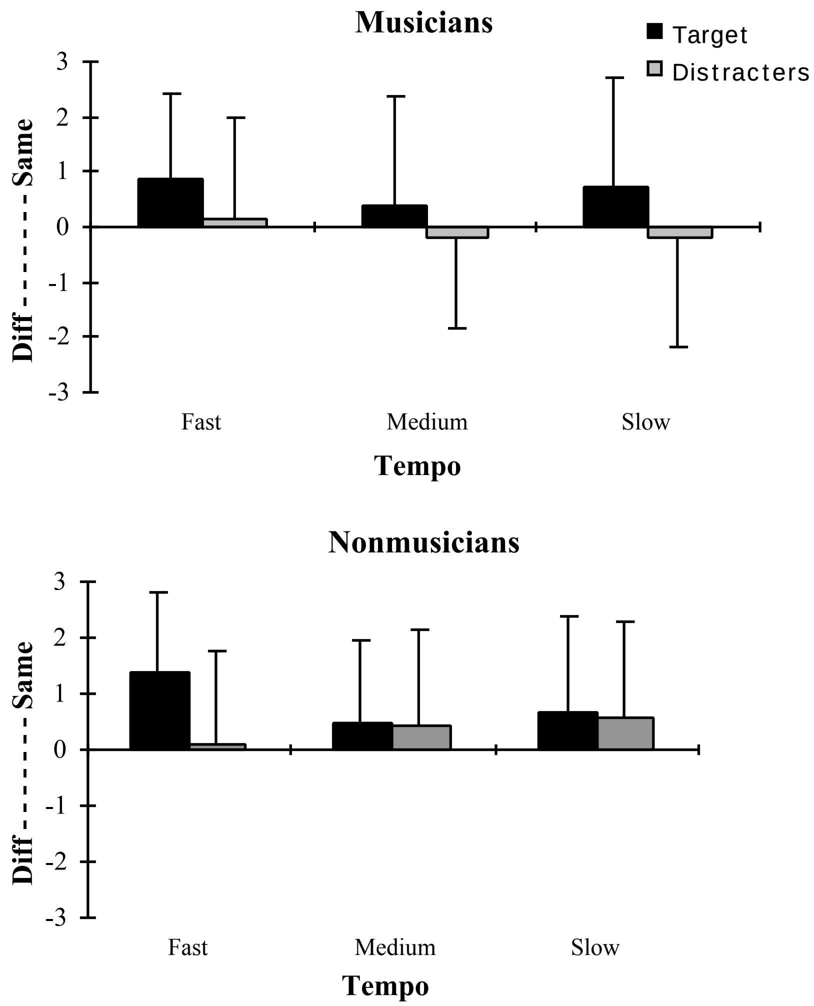



**Figure 7.14:** Target integrant recognition accuracy in musicians and nonmusicians as a function of tempo.

Tempo was found to affect the recognition of *aggregate* patterns in a complex manner. There were no effects of musical skill, but an interaction was observed between tempo, multipart rhythmic complexity (metrical versus nonmetrical), and distracter test item type (early versus late deviations). Recall that recency effects were found in aggregate pattern recognition: late deviations were detected better than early deviations, especially in metrical conditions (where the target integrant aspect of each multipart exposure item was metrical). The analysis of tempo effects reveals that these recency effects are more pronounced at the fast tempo in metrical conditions, and at the slow tempo in nonmetrical conditions (see Figure 7.15). Close examination of the data reveals that the effect is in fact due to differences in ability to detect early deviations – accuracy at late deviation detection is basically uniform across tempo and rhythmic complexity conditions. However, early deviation detection is most accurate at the *slow tempo* in metrical conditions (suggesting switching), whereas greatest accuracy at early deviation detection occurred at the *fast tempo* in nonmetrical patterns (suggesting parallel processing).

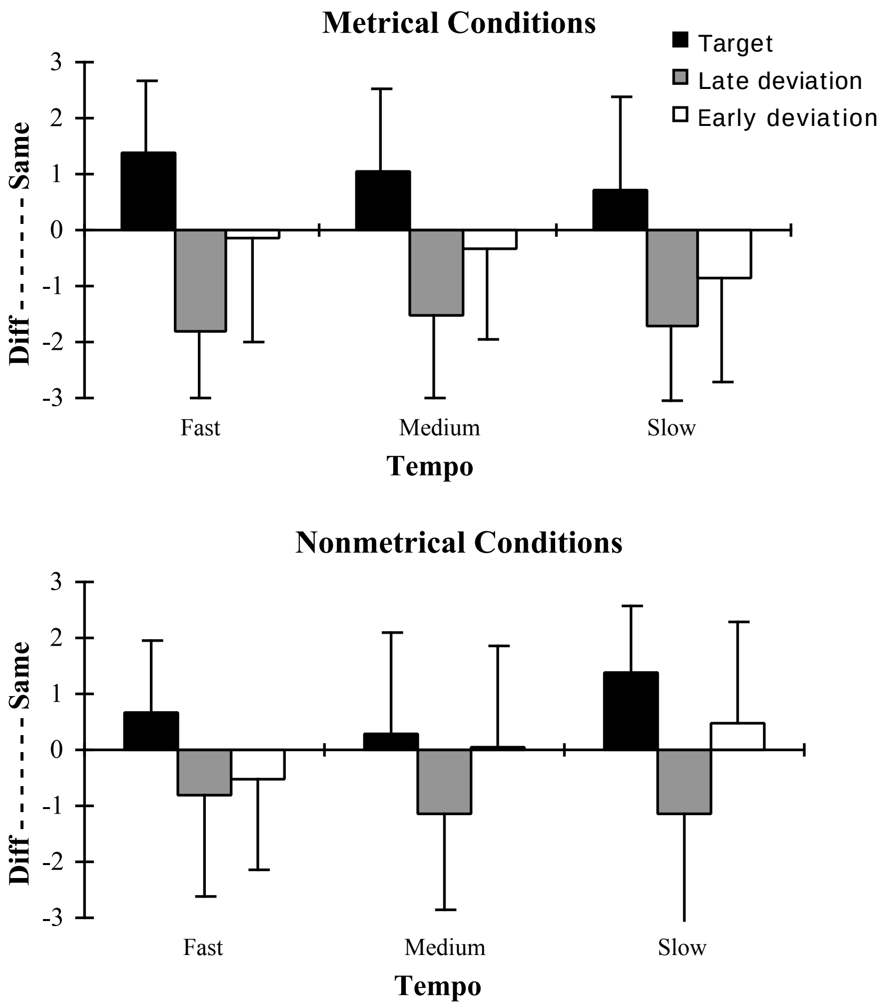



**Figure 7.15:** Aggregate recognition accuracy in metrical and nonmetrical conditions as a function of tempo.

These findings imply that rhythmic complexity affects timesharing strategy, and that strategy may in fact change during the course of attention to an unfolding pattern. It appears that listeners, on average, settled into a switching strategy fairly early during pattern presentation in metrical conditions, but did not do so in nonmetrical conditions, where parallel processing prevailed. Perhaps listeners use a passive parallel processing strategy at the onset of an encounter with a novel (or relatively unfamiliar) pattern, and then move to a more active switching strategy only if pattern structure is predictable and hence encourages such a shift. Thus, timesharing strategy may be quite mutable and responsive to the moment by moment demands that arise during the course of prioritised integrative attending.

Overall, the above examination of tempo effects has revealed that choice of timesharing strategy appears to be influenced by a whole range of factors, including tempo and rhythmic complexity (which are often related), as well as musical skill. Care will be needed in future research to disentangle these factors.

## 7.3 Conclusions

Multipart musical rhythm provides a touchstone for theories of musical rhythmic behaviour. Multipart textures are pervasive in musical interactions, and – if ecological adaptiveness is invoked – in more general forms of temporal interaction between an individual and their environment. Optimal behaviour in these contexts necessitates flexible attentional strategies that operate continuously in real time. These include, not only garden variety strategies such as selective and divided attention, but also a mode of attention not considered in previous research – prioritised integrative attending – which emphasises the relationship between the temporal patterning of one's own behaviour, on one hand, and the collective behaviour of all participants involved in the interaction, on the other. The ecological validity and significance of prioritised integrative attending are supported by the intuitions (elicited through the questionnaire study reported in Chapter 2) of practicing ensemble musicians. Indeed, musical ensembles can be seen as a suitable, readily controlled, microenvironment for investigating prioritised integrative attending.

A major theme of this dissertation concerns the role of metric frameworks in facilitating the attentional flexibility required for prioritised integrative attending. It was argued that metric frameworks promote this flexibility by providing a cognitive/motor schema-like mechanism for both *processing* and *representing* rhythm in an efficient manner. Thus, meter functions as an adaptive mechanism or resource that enables optimal dynamic attending strategies to be engaged, and coherent memory representations to be formed, in the context of complex musical interactions. The experimental work reported in Chapters 5 and 6 supports this conception fully. The multipart experiments from Chapter 6 are particularly noteworthy, as multipart rhythmic complexity has not previously been investigated under prioritised integrative attending conditions. The adaptive dual role of meter has implications for music education, methods of research, and theory development.

The concept of meter as an attentional resource was developed into a two-factor account of attentional resource allocation. The two-factor account proposes that through metric framework generation, resource availability and resource activity are modulated – in real time and continuously – in a manner that is both highly plastic and efficient, and hence conducive to the flexibility required for prioritised integrative attending. In addition to its role in explaining the effects of multipart rhythmic complexity, the two-factor account can be applied to a variety of other rhythmic phenomena (e.g., polyrhythm).

The two-factor account of resource allocation is the core of a broader theory of attentional resource allocation in musical ensemble performance (ARAMEP), which has been developed here. ARAMEP accounts for how prioritised integrative attending is influenced by various musical factors (e.g., rhythmic and pitch-based complexity) and extramusical factors (e.g., anxiety and arousal). The central claim is that these factors act directly upon cognitive/motor mechanisms, such as metric frameworks, that regulate attentional resource allocation during performance. Future work will quantify ARAMEP and evaluate its predictions for prioritised integrative attending. Another future goal is to apply ARAMEP to more general multiple task behaviours that – although not quite as pervasive and culturally significant as multipart musical rhythmic behaviour – rely on precise temporal regulation and resource allocation (e.g., aircraft control).

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