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ORIGINAL ARTICLE

Perceiving performer identity and intended expression intensity in point-light displays of dance

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Abstract This study investigated agent and expression intensity recognition in point-light displays depicting dancing performances. In a first session, participants danced with two different expression intensities to music, solo or in dyads. In a subsequent session, they watched point-light displays of 1–5-s duration, depicting their own, their partner's or another participant's recorded actions, and were asked to identify the agent (self vs. partner vs. stranger) and the intended expression intensity (expressive vs. inexpressive) of the performer. The results indicate that performer identity and expression intensity could be discerned reliably from displays as short as 1 s. The accuracy in judgment increased with exposure duration and, for performer identification, with higher expression intensity. Judgment accuracy in agent and expression intensity recognition tasks correlated with self-report empathy indices. Accuracy correlated also with confidence in judgment, but only in the intensity recognition task. The results are discussed in relation to perceptual and neural mechanisms underlying action and intention recognition.

Introduction

Communication contexts are prime targets for the study of human perception–action relations and the dynamics of social interaction. The ability to understand the actions, intentions, and emotions of others is an important aspect of human social cognition. Recently, much research has revealed a tight coupling between action execution and action observation (for reviews, see Rizzolatti & Craighero, 2004; Fabbri-Destro & Rizzolatti, 2008). Of particular interest for our current research are studies concerning self-recognition, intention recognition, and emotion recognition because they can provide insights about the various neural substrates, forms, and functions of perception–action links. Spatial and temporal aspects of actions are critical for activities that require precise motor control and coordination (Sebanz & Knoblich, 2009), such as ensemble music making (Keller, 2008). Specifically, in joint action settings, it is important to monitor, predict, and evaluate the intentions and actions of oneself and others, in order to achieve an optimal outcome, namely a coordinated performance. Therefore, the question is what sort of information do individuals perceive and how quickly do they perceive it when their goal is to understand the actions and intentions of the self and others. In particular, this study investigates individuals' accuracy and confidence in recognizing agents and their intended expression intensities when observing dance in brief point-light displays.

The tendency to recognize one's own actions and differentiate them from others' actions has been investigated using a number of different paradigms. The most prominent methods include visual observation of movement kinematics and listening to the auditory consequences of one's own as compared to other's actions. It has been shown that individuals are able to recognize their own actions by observing kinematic displays of drawing (Knoblich & Prinz, 2001), simple hand gestures such as finger tapping or line tracing (Daprati, Wriessnegger, & Lacquaniti, 2007), and complex full body movements, such as walking (Cutting & Kozlowski, 1977; Loula, Prasad, Harber, & Shiffrar, 2005; Sevdalis & Keller, 2009, 2010) or dancing (Loula et al., 2005; Sevdalis & Keller, 2009, 2010).

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Similarly, individuals are able to recognize whether sounds are controlled by their own tapping actions (Knoblich & Repp, 2009; Repp & Knoblich, 2007) and recognize themselves when listening to auditory consequences of their actions, namely, sounds associated with their clapping (Flach, Knoblich, & Prinz, 2004), or their piano performances (Repp & Knoblich, 2004; Keller, Knoblich, & Repp, 2007; Repp & Keller, 2010). A remarkable finding common to many of the above mentioned self-other discrimination studies is that self-recognition is still reliable even when the stimuli, provided for observation or listening judgments, have been manipulated so as to reduce the information they contain. Self-other discrimination seems to be possible based on the rather limited information.

In a similar way, social communicative signals, such as intentions and emotions, are readily perceived by observers in a variety of contexts. These signals are communicated by multiple channels, such as eye and gaze direction, vocal and facial expressions, and body movements. Although there is significantly less research concerning body movements and communication in comparison to other channels (De Gelder, 2009), a substantial amount of evidence shows that intentions and emotional states can be accurately encoded by and decoded from body movements. Specifically, neurophysiological and neuroimaging results suggest that simple grasping actions may reveal their intended meaning when observed by monkeys (e.g. grasping-for-eating vs. grasping-for-placing, Fogassi et al., 2005) and humans (e.g. grasping-for-drinking vs. grasping-for-cleaning, Iacoboni et al., 2005), even in conditions when the final part of the action is hidden from view (Umiltà et al., 2001). Similarly, behavioral experiments have shown that an agent's intention (e.g., to deceive) or affective state (e.g., happiness) can be reliably communicated to external observers in video or point-light depictions of actions, such as lifting a box (Grèzes, Frith, & Passingham, 2004; Runeson & Frykholm, 1981, 1983), basketball passing (Sebanz & Shiffrar, 2009), and in situations depicting various whole-body expressive gestures and movements, such as pointing (Manera, Schouten, Becchio, Bara, & Verfaillie, 2010), communicating (Clarke, Bradshaw, Field, Hampson, & Rose, 2005), walking (Chouchourelou, Matsuka, Harber, & Shiffrar, 2006; Roether, Omlor, Christensen, & Giese, 2009), or dancing (Dittrich, Troscianko, Lea, & Morgan, 1996).

Understanding the intentional or affective meaning of actions may not rely only on perceiving their visual features. For instance, intentions and actions can be communicated in the auditory modality by listening to an action's auditory consequences (Haggard, Clark, & Kalogeras, 2002; Kohler et al., 2002). In addition, in more complex music performance contexts, it has been shown that observers can identify performers' emotions or intentions for expression intensity when presented with visual, audio, or audiovisual recordings. Specifically, in such contexts, professional performers are usually instructed to perform musical pieces with the aim of expressing, for instance, different emotions (e.g., happiness) and subsequently observers are asked to identify the target emotion after watching and/or listening parts of the performance (e.g., Davidson, 1993; Dahl & Friberg, 2007; Broughton & Stevens, 2009). Thus, in a variety of situations and regardless of the communication modality, the agents' actions and the relation between the actions and features of the environment in which they are embedded may reveal their underlying intentional or affective properties by subtle differences in movement kinematics and their consequences.

Dancing is a prime example of a common spontaneous and often creative expressive behavior that has universal status and functional utility, for example in group bonding. The use of dance as a tool for interpersonal communication research enables the examination of behavior in naturalistic and ecologically valid settings, even in participants without formal musical training or dance expertise. Furthermore, dancing is an activity that most participants are naturally acquainted with, and as an experimental task it can be performed in solo and joint conditions. By implementing a design that uses non-expert participants' free style, spontaneous dance, in dyadic contexts, we aim to investigate human perception–action relations and their underlying mechanisms in interactive environments. In various situations, it has been shown that contextual cues, such as scenes surrounding the action (Iacoboni et al., 2005), presence of another agent (Sebanz, Knoblich, & Prinz, 2005) or relation to another agent (Loula et al., 2005) may have an impact on the way actions are both perceived and performed. In addition, there is evidence that even brief episodes of interaction between participants, even in simple tasks, may have an impact on their feelings about an interacting confederate (Hove & Risen, 2009; Miles, Griffiths, Richardson, & Macrae, 2010). Although individuals may differ in their ways of expression and their perceptual sensitivities, consistencies in expression and subsequent consistencies in perception can reveal underlying principles and mechanisms on which interpersonal communication is based. Performers and observers may share a common code for communication, regardless of communication modality, that supports action understanding (see Hommel, Müsseler, Aschersleben, & Prinz, 2001).

Previous research has demonstrated that, in the context of actions executed in synchrony with music, the performer's identity becomes more evident with increasing availability of kinematic information—that is to say, as kinematic complexity increases across different actions (ranging from clapping to dancing) and different versions of the same action (ranging from 2 to 15 marker point-light displays), without any additional benefit from auditory information (Sevdalis & Keller, 2009, 2010). Furthermore, it has been previously shown that the perception of biological motion embedded in a background of masking noise is facilitated with increased stimulus durations (Beintema & Lappe, 2002; Neri, Morrone, & Burr, 1998; Thornton, Pinto, & Shiffrar, 1998), although other studies have shown that short exposure durations may be sufficient for performance in tasks such as discriminating a walker's direction (Beintema & Lappe, 2002; Chang & Troje, 2008; Kuhlmann, de Lussanet, & Lappe, 2009), a walker's animacy (Chang & Troje, 2008), or coherence in the movement direction of a walker's body parts (Beintema, Georg, & Lappe, 2006; Beintema & Lappe, 2002) in point-light displays. In a similar way, performance in tasks such as anticipation of the direction of badminton strokes may be impaired with increased spatial–temporal occlusions (Abernethy & Zawi, 2007) and, conversely, spatial exaggerations may enhance recognition of emotions in facial expressions (Pollick, Hill, Calder, & Paterson, 2003), body movements (Atkinson, Dittrich, Gemmell, & Young, 2004), and agent identity (Hill & Pollick, 2000).

Taking into consideration these previous results, we expected that dancing actions differing in their dynamic spatial and temporal range (i.e., in their intensity and their duration) would provide different amounts of information for agent and intended expression intensity recognition, with higher dynamic action range facilitating recognition performance. At the same time, however, we expected performance to remain relatively high even under conditions of severely limited information. Minimal information specifying dynamic stimulus properties has been shown to be sufficient in a variety of domains and tasks, such as perceiving intentions and emotions in musical performances (Davidson, 1993; Dahl & Friberg, 2007), gender in point-light displays (Kozlowski & Cutting, 1977), affective states by arm movements (Pollick, Paterson, Bruderlin, & Sanford, 2001), and intentions in interactions (McAleer & Pollick, 2008). In addition, according to previous research, recognition of a human form as such, in point-light displays, is attainable with stimulus durations as short as 200 ms (Johansson, 1976), and self-recognition has been found to be reliable in 5-s point-light displays depicting dancing (Loula et al., 2005; Sevdalis & Keller, 2009, 2010).

To test the above hypotheses, we manipulated point-light displays of dance in two ways: we degraded the information by decreasing the intensity (i.e., amplitude) of the performer's movements by instructions to dance expressively versus inexpressively, and we reduced the duration of the point-light movies in five steps, from 5 s down to 1 s. The participants' task was to identify the agent (self, partner, or stranger) and the agent's intended expression intensity (expressive or inexpressive). Our prediction was that both agent recognition and intensity recognition would decrease as stimulus duration decreased. Moreover, we expected that agent recognition would be more difficult when the dancing was inexpressive than when it was expressive. A question of special interest was whether agent and/or intensity recognition would still be possible at stimulus durations as short as 1 s.

In addition, we introduced confidence in judgment as a dependent variable. Performance confidence, as a measure of subjective experience, can reveal whether there is any discrepancy between actual performance and subjective evaluation about performance. Individual participants may differ in their average degree of confidence in their judgments. In particular, judgments of agency are susceptible to cognitive bias, i.e., expectations, beliefs, and thoughts that can affect how much control people feel over actions and their consequences (Knoblich & Repp, 2009; Repp & Knoblich, 2007). Furthermore, for agency recognition, it has been suggested that there is a discrepancy between judgment of agency and feeling of agency, constituting two independent self-representational levels (Synofzik, Vosgerau, & Newen, 2008). We assume that a lack of correlation between participants' mean accuracy and confidence scores) in the agent recognition task would be consistent with hypothesis that judgments of agency (objective performance) and the feelings of agency (subjective evaluation of performance) are independent.

Finally, we wanted to examine whether there is any association between an individual's accuracy and confidence in the recognition tasks and self-reported interpersonal sensitivity indices (empathy scores). Interpersonal understanding may be associated with social-cognitive factors, such as a person's sensitivity towards a social stimulus or situation. Traditionally, emotional sensitivity has been evaluated by self-report questionnaires assessing constructs such as, for example, a person's capacity to empathize (de Vignemont & Singer, 2006; for a recent review see Singer & Lamm, 2009). It has been reported in behavioral and imaging studies that higher self-reported empathy (as assessed by scores in questionnaires) may be associated to various degrees with higher performance accuracy and/or higher activation of brain regions implicated in action understanding, theory of mind, and emotional processing. This has been observed in a number of tasks and situations, such as face recognition (Bate, Parris, Haslam, & Kay, 2010), perception of emotional expressions and actions (Decety & Chaminade, 2003; Pfeifer, Iacoboni, Mazziotta, & Dapretto, 2008; Schulte-Rüther, Markowitsch, Fink, & Piefke, 2007; Zaki, Bolger, & Ochsner, 2008, 2009), pain perception (Lamm, Batson, & Decety, 2007; Singer, Seymour, O'Doherty, Stephan, Dolan, & Frith, 2004), action perception (Gazzola, Aziz-Zadeh, & Keysers, 2006; Kaplan & Iacoboni, 2006), engaging in mimicry (Chartrand & Bargh, 1999), and disposition towards prosocial behavior (Davis, Mitchell, Hall, Lothert, Snapp, & Meyer, 1999; Eisenberg & Miller, 1987; Greitemeyer 2009). Based on this previous research, we hypothesized that empathy indices may have a positive relation to performance in the recognition tasks.

Methods

Participants

Ten adults (all females; aged 22–29; mean age 24.1 years) participated in the study in return for financial compensation. All of them reported to have normal hearing and normal or corrected to normal vision. None of them had previous experience with point-light displays. Participants were regular university students who had no extensive dance experience or focused training in a particular dance style. Participants did not know each other and were not informed about the experimental hypotheses. The treatment of the participants complied with the guidelines of the Max Planck Institute for Human Cognitive and Brain Sciences, where the research was conducted. All participants signed a consent form before the experiment began.

Design

The experiment was carried out in two sessions, separated by 6–7 months, in a within-subject design. Motion capture recordings of solo and dyadic dancing were made in the first (‘action’) session. Participants rated point-light displays generated from these recordings in the second (‘perception’) session. The independent variables of interest in the perceptual experiment were action display duration (5, 4, 3, 2, and 1 s), expression intensity (expressive and inexpressive), agent (self vs. partner vs. stranger), and self-reported emotional sensitivity (empathy scores derived from a questionnaire). The dependent variables were accuracy and confidence in the two tasks, agent recognition and expression intensity recognition.

Action session

Materials

Two novel pieces of funk music were created for use as stimuli. The pieces were created in Logic (Logic Pro 8, Apple Inc.). They had a clear beat structure and tempi (100 and 120 bpm for both pieces—i.e., 2 pieces × 2 tempi) that were selected to be movement inducing and to allow the two expression intensities (expressive & inexpressive) to be executed comfortably. The pieces were recorded in.wav format, and their duration was 70 s.

Equipment and procedure

For the action session, participants came to the laboratory twice, first to dance solo and then, a week later, to dance jointly with another participant. For the solo performance, participants came to the laboratory individually and were told that they would be required to dance in synchrony with two musical pieces and that their movements would be recorded. Participants were invited to execute the dancing action with two intentions for expression intensity (expressive versus inexpressive), in time with each of the two musical pieces. In the ‘expressive’ condition, participants were instructed to dance to the pieces as they would naturally. In the ‘inexpressive’ condition, participants were instructed to dance with less expression than in the expressive condition. The inexpressive condition always followed the expressive one.[1] Participants were told that this experiment was not a test of their dancing abilities and that they should simply listen to the music and move in time with it as naturally as possible, as they would ordinarily do when dancing outside the laboratory. Participants confirmed that they understood the instructions. Our purpose was to leave space for each individual’s unique movement signature to unfold.

Participants danced with one of the two different expression intensities for the entire duration of each piece. The starting position and the dancing space were clearly indicated by white tape on the floor. The total available dancing space in the laboratory was a square of 280 × 280 cm, divided into two rectangles of 280 × 140. In the solo dancing condition, each individual participant was assigned randomly to either the left or the right rectangle and was instructed to contain her performance within this area, without crossing the midline. This instruction was given for the subsequent creation of clear (one-dancer) point-light displays (i.e., without the persons overlapping, as would have been the case if participants had decided to move in circles or to remain both on one side of the space). The space available (280 × 140 cm) enabled moving comfortably in every possible direction. Participants could use the space freely. After the two expression intensities had been executed for the first musical piece, the same procedure was repeated for the second musical piece. The orders of the pieces and of the tempi were counterbalanced. The duration of the action session did not exceed 1 h.

Performances were recorded by a Vicon motion capture system (Vicon, Oxford, UK). Thirty-two reflective markers

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[1] Kinematic analyses showed that the total distance travelled in space for each of the 13 motion capture markers attached to the dancers’ bodies (see below) was significantly higher in the expressive than in the inexpressive displays: $ts > 16.95$, $ps < 0.001$. This confirmed that the experimental manipulation had an effect on action execution, and that the participants were following the instructions.

were attached to the participants' bodies, at the top of the head, the main joints, and other body parts (based on Vicon's PlugIn gait marker placement model). Ten cameras were placed at approximately equal distances from the center of the room. Data acquisition, with a sampling frequency of 200 frames per second, was controlled by Vicon Nexus software. At the start of each musical excerpt, a digital signal was sent to a trigger panel consisting of a bank of light emitting diodes, thus enabling the precise onset time of the audio signal to be recorded along with the motion capture data. Performances were also videotaped by a digital video camera (SONY HDR-HC9).

After 1 week of the solo performance, the same participants were invited back to dance together with a partner (who had also acted previously as a solo dancer). Participants were matched in pairs according to physical body proportions. The matching process was carried out in the same way as in previously published studies (Loula et al., 2005; Sevdalis & Keller, 2009, 2010). Matching participants according to physical body proportions ensured that weight and body mass (Runeson & Frykholm, 1983) could not be used as the basis for participants' responses in the subsequent recognition tasks. Thus, five matched pairs were created and were invited to dance together. For the joint session, the entire 280 × 280 cm space was used. Participants who previously danced within the left rectangle of the dancing space were assigned to the right and vice versa. Both were instructed to dance within their own rectangle, without crossing the midline. Participants, again, used the space freely. The distance between the dancers at the starting positions, facing each other, was 110 cm (roughly double of the limit of each participant's peripersonal space; with the arms extended, participants could touch each other's fingertips). All the other aspects of the performance were the same as in the previous individual session. At the end of the joint session, a questionnaire was administered to assess each participant's views and feelings about the interaction and the relationship to their partner.

Perception session

Materials

Point-light movies were prepared using Final Cut Pro and QuickTime Software. Out of the original 32 markers, 13 markers were retained for generating the stimuli, those at the head and the main joints (see Fig. 1). The onset times of motion capture and audio data were synchronized by aligning the motion capture files of the participants in profile views (left and right) with the motion capture files of the trigger panel onset signals and with the audio files. From each combination of 2 expression intensities × 2 musical excerpts, three 5-s excerpts were selected from the dancing sequences (i.e., 20–25, 30–35 and 40–45 s out of all the 70 s sequences) for use as stimuli. To the original dyad ('self' and 'partner'), one more participant was added (as 'stranger') from another dyad, again by taking into consideration the participants' body proportions (i.e., for every 'self' there was one 'partner' and one 'stranger'). Thus, five matched triads were created. The point-light movies displayed the performances of the two different expression intensities (expressive vs. inexpressive) and of the three different agents (self vs. partner vs. stranger) with or without the accompanying music.

In total, for each dancer, 96 point-light movies were created that contained all the possible combinations of 2 intensities (expressive and inexpressive), 2 observing conditions (visual and audiovisual), 2 musical pieces (1st and 2nd piece), 2 tempi (100 and 120 bpm), 2 contexts

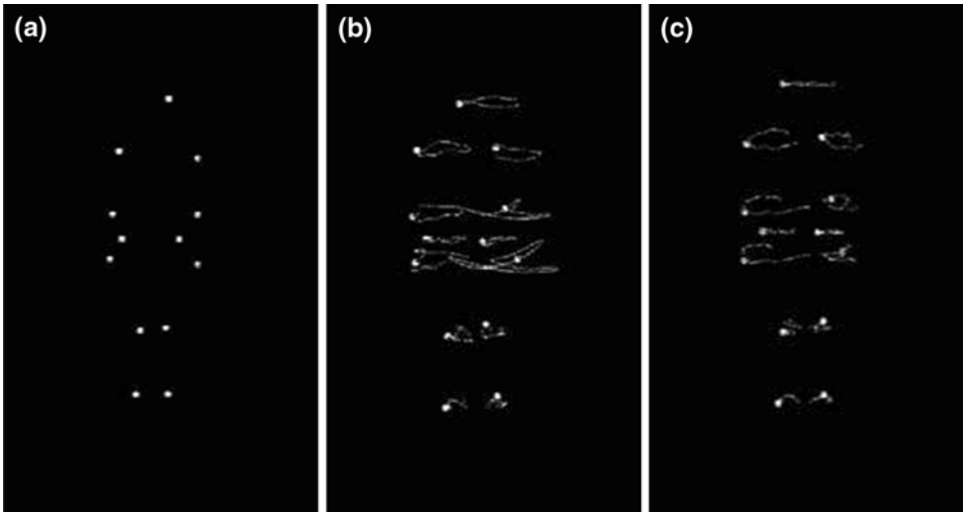

Fig. 1 Point-light depiction of a dancer with 13 markers attached at the head and the main joints of the body in the start position (**a**), expressive condition (**b**), and inexpressive condition (**c**). The *line traces* indicate marker movement trajectories over a 1-s window

(solo and dyad), and 3 different selections of each action (20–25, 30–35 and 40–45 s).[2] In addition, for introducing the action duration manipulation in a counterbalanced fashion, we used a latin square for the triads and the selections. The first triad saw 1 s from selection 1 (s1), 2 s from selection 2 (s2), 3 s from selection 3 (s3), 4 s from s1 and 5 s from s2. The second triad saw 1 s from s3, 2 s from s1, 3 s from s2, 4 s from s3 and 5 s from s1. The same procedure was applied for the remaining three triads. Thus, each individual observed a total of 480 trials [3 agents (self-partner-stranger) × 32 point-light movies (according to selection) × 5 durations].

Equipment and procedure

After 6–7 months, the same participants returned and watched the point-light movies on a computer monitor. The point-light figures were projected at a size extending over 11.42° of visual angle; their height was $\sim$10 cm and the viewing distance was about 50 cm for all the participants. The session started with the participants watching a block of 12 practice trials, 4 for ‘self’, 4 for ‘partner’, and 4 for ‘stranger’ in random order. Then, each participant watched 480 point-light movies presented in random order (160 ‘self’, 160 ‘partner’, and 160 ‘stranger’ movies). Before each trial onset, a white fixation cross appeared at the center of the monitor, lasting for 1 s. The participant pressed the spacebar to initiate each trial. The auditory information (i.e., the music that accompanied the dancing) was delivered over headphones (Sennheiser HD 280 PRO).

The tasks for the participants were the following: (a) to indicate whether the depicted agent was oneself, one’s previous partner, or another person; (b) to rate their confidence about their agent judgment on a 6-point scale (with anchors: not at all confident—very confident); (c) to indicate the agent’s expression intensity (expressive vs. inexpressive), and (d) to rate their confidence in their expression intensity judgment, on a similar scale as that used for agent. Responses were registered by mouse click on correspondingly labeled squares on the computer monitor (i.e., for the first task the left square was labeled ‘Du selbst’, indicating ‘yourself’, the middle square was labeled ‘Deine Partnerin’, indicating ‘your partner’, and the right square was labeled ‘jemand anderes’, indicating ‘someone else’). No feedback about correctness was provided after responses.

At the end of the experiment, participants were administered the Interpersonal Reactivity Index (IRI) questionnaire (Davis, 1980) for the assessment of empathy dispositions. The IRI is a 28-item self-report questionnaire that contains four subscales: Empathic Concern, the tendency to feel compassion toward others; Perspective Taking, the tendency to take the point of view of another person; Fantasy, the tendency to relate to fictional characters; and Personal Distress, the tendency to feel negative emotion in stressful situations. Each question is answered using a 5-point Likert’s scale (anchors: Does not describe me at all—describes me very well). The perception session lasted for 1.5 h.

Results

First, we describe the results of the questionnaire addressing participants’ appraisals of the joint dance session, and, then, we report the results of the perceptual tasks assessing agent recognition and expression intensity recognition.

Participants’ views and partner appraisals

Data yielded by the questionnaire assessing participants’ views and feelings about the interaction and the relationship to their partner are shown in Table 1. These data suggest that the interaction between participants was rather fluent and reciprocal. For the question about liking the experiment after doing it (i.e., dancing) with a partner relative to dancing alone, 8 out of 10 individuals reported liking the experiment more in the joint session than in the solo session; the other 2 liked it equally in both sessions. For the question about difficulty of the experiment, all of them reported that it was of equal difficulty in solo and joint conditions ($n = 7$) or easier ($n = 3$) in the joint condition. The participants also reported that the styles they would prefer to dance to—or have danced to—were diverse, including classic, jazz/modern, latin, rock, pop, hip-hop, disco, and electronic.

Perceptual tasks

Agent recognition and expression intensity recognition were assessed by computing d'. For agent recognition, we conducted two d' analyses: first, self versus others (partner and stranger, averaged) and, secondly, partner versus stranger. For the intensity recognition task, we computed the discrimination for expressive versus inexpressive conditions. The d' measure takes response bias into account by subtracting z-transformed false alarm rates (‘self’-judgments

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[2] In a preliminary analysis, observation condition (visual vs. audiovisual, i.e., with the original music being played along with the point-light movies) was included as an independent variable in the analyses, in order to compare the results with findings in our previous studies (Sevdalis & Keller, 2009, 2010). These analyses did not yield any differences between the observation conditions, thus, replicating our previous results. Henceforth, we dropped the observation condition variable from the analyses. Furthermore, we collapsed across musical piece, tempo, context, and selection, because these variables were not directly relevant to our research aims.

Table 1 The questions were answered on rating scales ranging from 1 to 5 (anchors: not at all—very much) or scales with three different alternatives (e.g., less—the same—more)

Question	Mean (STD)
Do you like dancing to music?	4.4 (1.07)
How often do you dance to music?	3.9 (0.88)
Did you like the experiment?	4.1 (0.74)
*How did you like the experiment now that you have done it with another person?	2.8 (0.42)
Was the experiment difficult?	1.5 (0.71)
*How difficult was the experiment, now that you have done it with another person?	1.7 (0.48)
When you were dancing, did you take into account the movements of your partner?	3.0 (0.66)
When you were dancing, did you try to react to the movements of your partner?	3.1 (0.88)
How often did you try to imitate the movements of your partner?	2.3 (0.95)
How often did you take inspiration from the movements of your partner?	2.5 (0.53)
Did you pay attention to the facial expressions of your partner?	3.8 (1.03)
Did you try to react to the facial expressions of your partner?	3.3 (1.25)
Did you try to imitate the facial expressions of your partner?	2.4 (1.26)
How much did the presence of your partner influenced the way you danced to music?	2.8 (0.92)
When you were dancing, do you think your partner took into account your movements?	2.9 (0.88)
When you were dancing, do you think your partner took into account your facial expressions?	2.8 (1.03)
*How coordinated ('in sync') you were with the music, now that you have done the experiment with another person?	2.0 (0.66)
How much coordinated ('in sync') you think you were with your partner?	3.7 (0.48)
How much coordinated ('in sync') you think your partner was with you?	3.6 (0.70)
How friendly were you to your partner?	4.3 (0.67)
How friendly was your partner to you?	4.6 (0.52)
How much did you like your partner?	4.3 (0.95)
How much do you think your partner liked you?	4.1 (0.74)

An asterisk '*' beside a question in the table indicates that the answer was given on a 1–3 scale

for 'others' displays, and 'partner' for 'stranger' displays in the two analyses concerning the agent recognition task, respectively, and 'expressive' for 'inexpressive' displays in the intensity recognition task) from hit rates (correct 'self', 'partner' and 'expressive' responses in the two tasks, respectively) (see Macmillan & Creelman, 1991). High d' scores indicate accurate performance.

Agent recognition

The results for the self versus others (partner and stranger, averaged) analysis are shown in Fig. 2. According to t tests, agent recognition accuracy was significantly better than chance ($d' = 0$) for all duration levels in the expressive condition, even for 1 s [$t(9) = 3.61, p = 0.006$], and for 2, 4 and 5 s in the inexpressive condition [5 s, $t(9) = 3.01$, $p = 0.015$; 4 s, $t(9) = 3.94$, $p = 0.003$; 3 s, $t(9) = 1.76$, n.s.; 2 s, $t(9) = 2.60$, $p = 0.029$; 1 s, $t(9) = 1.15$, n.s.]. In raw scores (chance performance is 33.3%, since the task was a 3 alternative forced choice task), when collapsed across all conditions, correct recognition performance (i.e., self as 'self', partner as 'partner' and stranger as 'stranger') ranged from 67.71% (SE 5.93) at 5 s to 59.11% (SE 4.41) at 1 s.

A 2 × 5 repeated measures analysis of variance (ANOVA) was conducted on d' scores to test our hypotheses about the effects of duration and expression intensity on agent recognition. This analysis revealed statistically significant main effects of duration, $F(4, 36) = 6.13$, $p = 0.001$, and of expression intensity, $F(1, 9) = 28.76$, $p < 0.001$. A trend analysis indicated the duration effect increased linearly across duration levels: $F(1, 9) = 10.06$, $p = 0.01$. The interaction between duration and expression intensity was not significant $F(4, 36) < 1$, n.s.

The analysis addressing whether participants could discriminate partner versus stranger did not yield any significant results. Performance was at chance for all duration levels [$ts(9) < 2.19$, n.s.] and there were no main or interaction effects of duration or expression intensity [$Fs < 1.56$, n.s.].

A correlation analysis was conducted to investigate any association between performance in the agent recognition task and individual differences in empathy. This analysis revealed a significant positive correlation between the average empathy score and performance: $r = 0.64$, $p = 0.046$. Correlations with the scores of the four subscales of the IRI did not reach significance.

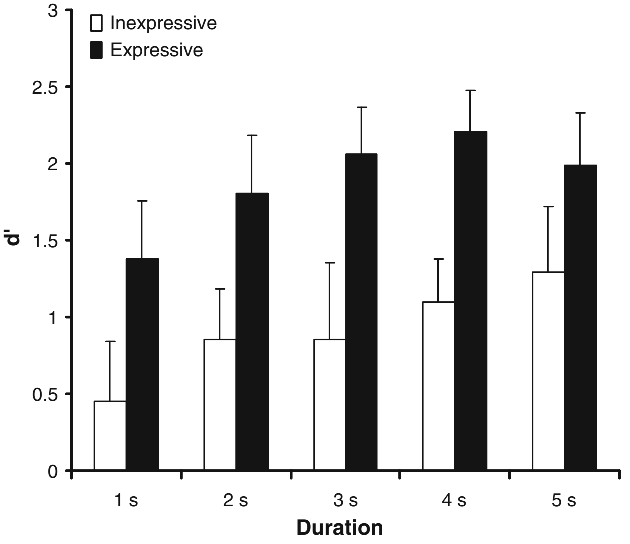

Fig. 2 Average d' scores for self-recognition in the five duration conditions for the two expression intensity levels. *Error bars* indicate standard error

Finally, the correlation between confidence scores and mean performance across participants did not reach significance ($r = 0.52$, $p = 0.13$). Thus, it was not the case that high individual accuracy was associated with reliably high confidence in judgment. A correlation analysis examining relations between empathy scores and confidence about agent identity judgments revealed no significant correlation. Correlation analyses also revealed no systematic relationships between participants' views and partner appraisals with performance in the agent recognition task.

To summarize, agent recognition accuracy for point-light displays of dance improved with increasing availability of kinematic information (i.e., with increasing duration and expression intensity), but agents were still reliably recognizable in displays of very short duration for displays containing more expressive information. Although better than chance recognition performance was possible even in some inexpressive conditions, participants seemed to need more time (3 s or more) to make the correct judgment when there was less kinematic information available. The tendency to recognize agents was positively correlated with the average empathy score, indicating that, the tendency to score high in questions regarding the understanding of others' situations and feelings may be associated with performance in the agent recognition task. Across individual participants, accuracy and confidence of judgments were more or less independent of one another.

Intended expression intensity recognition

The results for the expressive versus inexpressive analysis are shown in Fig. 3. Intensity recognition accuracy was significantly better than chance ($d' = 0$) for all duration and agent conditions, even at 1 s, $ts(9) > 5.79$, $p < 0.001$. In raw scores, when collapsed across all conditions, correct expression intensity recognition performance (i.e., inexpressive as 'inexpressive' and expressive as 'expressive' ranged from 77.19% (SE 1.47) at 5 s to 74.48% (SE 1.59) at 1 s.

A 2 × 5 repeated measures analysis of variance (ANOVA) revealed statistically significant main effects of agent, $F(2, 18) = 4.44$, $p = 0.027$, and of duration, $F(4, 36) = 3.22$, $p = 0.023$. Paired sample t tests revealed that the difference between the 'self' and 'partner' condition was not significant ($t(9) = 1.00$, n.s.), while the difference between 'partner' and 'stranger' was significant ($t(9) = 2.64$, $p = 0.027$). The duration effect was characterized by a significant linear trend, $F(1, 9) = 6.57$, $p = 0.03$, and a significant fourth-order trend, $F(1, 9) = 8.53$, $p = 0.02$ (The latter was unexpected, and is most likely due to the dip in intensity recognition for self and partner in 4-s displays.) The interaction between duration and agent was not significant $F(8, 72) < 1$, n.s.

A correlation analysis examined relations between empathy scores and the accuracy of expression intensity judgments. This analysis revealed a significant positive correlation between perspective taking scores and judgment accuracy: $r = 0.65$, $p = 0.042$.

Finally, there was a significant positive correlation between confidence scores and mean performance of individual participants: $r = 0.80$, $p = 0.006$. Thus, high accuracy was associated with high confidence in judgment. A correlation analysis examining relations between empathy scores and confidence about expression intensity judgments

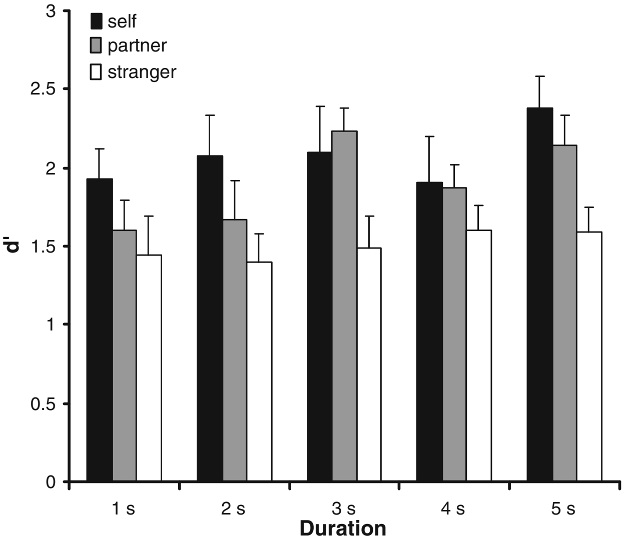

Fig. 3 Average d' scores for expression intensity recognition in the five duration conditions for the three types of agent. *Error bars* indicate standard error

revealed no significant correlation. Participants' views and partner appraisals also did not enter into significant correlations with performance in the expression intensity recognition task.

To summarize, intended expression intensity recognition accuracy for point-light displays of dance improved with increasing availability of kinematic information (i.e., increasing duration). The expression intensity was still reliably recognizable in displays of very short duration. Furthermore, the tendency to recognize intensities was positively correlated with the average perspective taking scores suggesting that the tendency to take the point of view of another person may improve performance in the intensity recognition task. The accuracy and confidence of judgments were positively associated with one another.

General discussion

The aim of this study was to investigate the role of spatial–temporal cues and empathy in the recognition of agent identity and intended expression intensity in point-light displays of dance. Agent and intended expression intensity recognition accuracy improved with increasing availability of kinematic information (i.e., increasing duration and expression intensity), and in both tasks, agents and intensities could still be recognized reliably in the case of displays of very short duration, even as short as 1 s (for agents, only in the 'expressive' conditions). In addition, the results revealed some evidence that discrimination performance in these tasks may be associated with empathy indices.

Our experiment shows that visual information about personal movement kinematics is sufficient for agent and expression intensity recognition, even under impoverished conditions (i.e. point-light displays of 1 s duration). The current findings extend research on the links between action execution and action perception that have been previously found in tasks of self-other discrimination (Sevdalis & Keller, 2009, 2010). The sensitivity of the action observation network evidently depends on the spatial and temporal dynamic range of the action: relatively intense and spatially unconstrained movements (i.e., expressive) and temporally unoccluded actions (i.e., of considerable duration) are particularly potent due to richness in visual information about personal styles of action execution. It should be noted that participants in our study performed the perceptual tasks with minimal training, without any feedback, and without having any previous experience with point-light displays.

Our results suggest that both agent and expression intensity recognition can be performed accurately within brief time windows. As far as the agent recognition task is concerned, accuracy judgments of agent identity are enhanced by the availability of kinematic information (i.e., expression intensity and duration), with increased empathy indices also being associated with good performance. However, the accuracy and confidence in the agent recognition task appeared to be rather independent at an individual level (see also Synofzik et al., 2008). The best performance for one's self versus others, along with the lack of perceptual sensitivity in discriminating partner versus stranger, implies that motor experience is more relevant to agent recognition than visual experience (e.g., memory for the actions of the partner with whom they interacted) (cf. Loula et al., 2005; also Repp & Knoblich, 2004).

As far as the intended expression intensity recognition task is concerned, accuracy in judgments seemed to be enhanced by the availability of kinematic information (i.e., duration), although the high performance at short duration limited the increase in accuracy that could be observed as duration increased. Confidence appeared to be interdependent with accuracy. In addition, the current results suggest that performance in this task may be also associated by the self-reported tendency to evaluate situations from another person's point of view. In the intensity recognition task, motor and visual experience seems to have more complementary roles. Although participants were best in recognizing their own intended expression intensities, there were no significant differences in recognizing one's own versus one's partner's intensities; only identification of a stranger's intensities was significantly less accurate. The lack of difference in performance between self and partner may indicate that interaction with a partner (i.e., visual experience with their movement style) may facilitate recognition performance (cf. Cross, Kraemer, Hamilton, Kelley, & Grafton, 2009). Taken together, the current results imply that performance in the two tasks may be mediated by a combination of cues provided by movement kinematics along with benefit from empathic tendencies.

The increased amplitude and duration of displayed spontaneous dancing actions can provide salient features and create a stronger impression of the agent of the action. In corroboration of previous research that showed that increased action complexity (Sevdalis & Keller, 2009) and increased availability of information (Sevdalis & Keller, 2010) enhances agent identity perception, the current research shows that the process of inferring the actions and intentions of others relies on dynamic information about human movement, such as expression intensity and duration. Higher dynamic action range parameters can boost resonance in the observer's motor system, and, therefore, lead to enhanced sensitivity to small differences between kinematic patterns specifying underlying stimulus properties (Loula et al., 2005; Sevdalis & Keller, 2009, 2010).

The process of decoding agents, actions, and intentions in movement may be related to the degree of empathizing with the encoders of the action. Recently, neuroimaging experiments have shown that common neural circuits are activated when observing sensations or emotions felt by others, and when experiencing these sensations and emotions oneself (for a recent review, see Bastiaansen, Thioux, & Keysers, 2009). In addition, it is also possible that expressive movements produce more salient or 'readable' cues or more 'affective language'. Therefore, individuals who report high scores on dimensions of empathy may attend to and elaborate on their own and others' affective reactions more than individuals, who report low scores. Nevertheless, the potential direction of causation may be manifold, with action simulation and reported emotional sensitivity being equally potent as causal forces: A higher emotional sensitivity may facilitate 'resonating' with one's own and others' actions, intentions, and emotions, but also, a higher tendency to resonate may lead to higher reported emotional sensitivity to the expression of one's own and others' dancing. Possibly, even other factors, such as availability and reliability of spatial–temporal information may modulate both resonance and empathy processes. Therefore, these conclusions should be considered tentative, especially since the correlation results were obtained with a small number of participants. The potential links between action perception and empathy warrant further investigation.

In the light of previous research that reported that 200 ms may be a perceptual threshold for perceiving a human form as such when depicted in point-light displays (Johansson, 1976), the current findings of accurate recognition from displays lasting 1 s imply that the process of behaviorally decoding elementary (e.g., a human form) and higher level (e.g., an agent's identity and intended expression intensity) stimulus properties depicted as point-light displays may occur within a window of 200–1,000 ms. This possibility may further be explored by investigating patterns of neural activation when observing intentions and actions, by applying, for instance, EEG methodology.

Which mechanisms underpin this rapid processing of action-related social information and the subsequent effortless recognition of agent identity and intentions? It has been proposed that embodied simulation, relying on the mirror neuron system—and its interface with the amygdala via the anterior insula—plays an instrumental role in social interaction by establishing a direct link between one's own and others' actions, intentions, and emotions (Gallese, Keysers, & Rizzolatti, 2004). This 'intentional attunement' may stem from an activation of shared neural systems underpinning one's own and other's actions (Gallese, 2006). Action understanding, via the mechanism of simulation of others' actions, has also been related to the tendency to empathize with others. Specifically, Preston and de Waal (2002) proposed a neuroscientific model of empathy suggesting that observation or imagination of another person in a particular emotional state automatically activate a resonance/matching of that state in the observer with its associated autonomic and somatic responses. Performers and observers may also share a common code that supports the sharing and communication of the meanings of one's own intentions and actions with others: despite individual differences in expressing and perceiving actions, there may be considerable consistency in both action execution and perceptual sensitivity processes, thereby enabling a tight coupling between the two.

This coupling, which perhaps stems from long evolutionary processes (e.g., Gallese, 2009) may have a functional utility for social cognition. Action and intention understanding may be based on the spatial–temporal dynamics of social interaction, with expressive information being of social benefit and serving as a prerequisite for understanding other's intentions, for coalescing with their actions and emotions, and for coordinating behavior between interacting partners. Successful joint action and cooperation may depend on the natural tendency to infer what type of beliefs and action intentions other people have (Tomasello, Carpenter, Call, Behne, & Moll, 2005). The current study showed that a simulation mechanism on which such an immediate process may rely can be modulated by the interplay of spatial–temporal cues (e.g., expression intensity and duration) and cognitive–emotional indices, such as sensitivity tendencies (e.g. self-reported empathy indices).

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