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Bodily bonds: effects of social context on ideomotor movements

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Introduction

In David Mitchell's latest novel, 13-year-old Jason Taylor observes a fight among some of his rather brutal classmates. As he later reports, seeing one of the bullies leashing out at a weaker kid, "my own body flinched under the punches, automatically, like how your leg hoists itself when you're watching a high jumper on TV" (2006, p. 75). This captures an experience we have quite frequently when observing others' actions: There seems to be a mysterious bodily bond between ourselves and others that makes us draw back in our seat when a movie character is heading towards an abyss, has us kick our legs when we watch our favorite soccer player trying to score a goal, and makes us bounce our knees when we see a kid jumping up and down on the trampoline. Such movements occurring in response to observed actions are referred to as 'ideomotor movements' (Knuf *et al.*, 2001). They are of interest to researchers studying perception–action links because they can provide insights as to how one's own body is involved in the perception of others' actions.

Two different kinds of ideomotor movements have been identified in previous studies (De Maeght and Prinz, 2004). On the one hand, observers sometimes re-enact or mimic an actor's movements, acting as if they were the observed rather than the observer. Such 'perceptually induced' ideomotor movements may be explained by the fact that when we observe someone performing an action, corresponding representations in our own action system are activated (for recent reviews, see Viviani, 2002; Buccino *et al.*, 2004; Rizzolatti and Craighero, 2004; Wilson and Knoblich, 2005). This phenomenon will be referred to as 'motor resonance'.

On the other hand, compensatory rather than imitative movements occur when observers watch someone who is experiencing difficulties achieving a goal or who is about to fail in some way, such as when someone is close to falling off a cliff. Such compensatory movements are of particular interest because they suggest that the assumption that action perception always triggers a tendency to execute the same action may be oversimplified. Rather, compensatory ideomotor movements are also known as 'intentionally induced' movements, because they seem to reflect the observer's awareness of the actor's intention. By this interpretation, intentionally induced ideomotor movements reflect the interaction of sensorimotor processes with mental states.

To date, only a few studies have investigated ideomotor movements, and very little is known about the factors that determine whether people produce imitative or compensatory movements while watching other people's actions. As will be discussed below, possible factors that could modulate the degree to which motor resonance takes place include the psychological relationship between actor and observer, the nature of their interaction, and the spatial relation of their bodies. A closer understanding of the factors modulating motor resonance is critical for understanding the social functions of perception–action links (Knoblich and Sebanz, 2006). In the following, we will provide a short overview of ideomotor theory, which provides a foundation for the empirical study of ideomotor movements. In a next step, we will review studies that speak to the question of how social context modulates motor resonance. We then report two experiments that investigated the role of shared orientation on ideomotor movements.

From magic to ideomotor theory

The notion of a close link between perception and action has received considerable attention in recent years, spurred by the discovery of mirror neurons in macaque premotor (Gallese *et al.*, 1996) and parietal (Fogassi *et al.*, 2005) cortex. These much-discussed neurons fire both when a monkey performs an action and when the monkey observes someone performing the same action (Rizzolatti and Craighero, 2004). However, theoretical roots supporting the notion of a close link between perception, imagination, and execution of action can be traced back to the work of Carpenter (1874) and James (1890), who developed ideomotor theory (for a historical overview, see Knuf *et al.*, 2001). Carpenter was concerned with the question of how ideas guide movements without or against the actor's voluntary control. He referred to all action that is produced involuntarily, through a strong idea or image, as 'ideomotor action'. By assuming that ideas or mental images can directly trigger movements, he was able to account for a range of phenomena that seemed magic at the time, including the swinging of a hand-held pendulum despite instructions to hold it still.

Based on Lotze's work, James (1890) developed a theory of voluntary action based on the idea that "… every representation of a movement awakens in some degree the actual movement which is its object" (Vol. 2, p. 526). Simply put, thinking about a particular action effect creates a tendency to perform this action, as long as no conflicting thoughts are present. For example, thinking about a light turning on may trigger the action of operating the light switch. According to ideomotor theory, such regularities between movements and their more or less distant perceivable consequences are represented through learned associations (Knoblich and Prinz, 2005).

Greenwald (1970, 1972) realized that the ideomotor principle can be extended from imagination to the perception of action. If thinking of perceivable events triggers the movements that produce them, then perceiving the same events in the environment, e.g. as the result of somebody else's action, should also create a tendency to perform the movements that produce the observed events. For example, seeing a light turn on (rather than thinking about this effect) may activate a representation of the action of operating the light switch. Through this extension, ideomotor theory not only provides a functional principle for understanding voluntary action, but also offers a theoretical framework for understanding links between action perception and action production. A basic interpersonal link is provided by the assumption that perceived actions (performed by others) and planned actions (performed by oneself) are coded in a common representational domain (Prinz, 1997; Hommel *et al.*, 2001).

Constraints on motor resonance

Behavioral (e.g. Brass *et al.*, 2001), brain imaging (e.g. Stevens *et al.*, 2000; Calvo-Merino *et al.*, 2005), and neurophysiological studies (e.g. Fogassi *et al.*, 2005) have confirmed that when we observe someone performing an action, corresponding representations in our own action system are activated, creating a tendency to perform the observed action. For example, behavioral studies have shown that the execution of an action is facilitated when one concurrently observes someone making a similar movement, while it is impaired when one observes someone making an opposite movement (Stuermer *et al.*, 2000; Brass *et al.*, 2001; Kilner *et al.*, 2003). Interestingly, the findings by Kilner *et al.* suggest that these effects might be restriced to the observation of human motion and do not apply to the same extent when humans observe robot movements that have different kinematics.

A compelling demonstration of our tendency to covertly simulate observed actions was recently provided by Flanagan and colleagues (Flanagan and Johansson, 2003; Rotman *et al.*, 2006) who measured the gaze patterns of people performing a block-stacking task while observing another person performing the same task. They found highly similar gaze patterns for action perception and execution, suggesting that as people were watching the other's hand movements, corresponding action plans were activated. Flanagan *et al.* concluded that these action plans entail eye motor programs directed by motor representations of the manual actions. In other words, participants covertly simulated the observed hand actions, which led them to perform eye movements they would normally make when performing the observed actions themselves. Thus, the eyes provided a rare window into the mind, as action observation usually does not lead to overt action execution.

The relationship between self and other

While covert simulation may be the default (Wilson and Knoblich, 2005), there are instances where action representations are activated so strongly by observation that one finds oneself doing what one's interaction partner just did. For example, when talking to each other, people often engage in nonconscious mimicry, unwittingly imitating the postures, mannerisms or facial expressions of their interaction partner (for an overview, see Chartrand and Bargh, 1999). For example, Chartrand and Bargh (1999) showed that participants performing a task together with a confederate who shook her foot were also more likely to shake their foot, whereas participants paired with a confederate who rubbed her face rubbed their face more often. How can action observation lead to overt simulation given that the observer has no intention to imitate the other? One possible explanation is that nonconscious mimicry occurs when inhibitory processes that normally keep us from executing observed actions (Wilson, 2003; Brass *et al.*, 2005) are overridden. Evidence for this assumption is provided by the study of patients with frontal lobe lesions, who show a tendency to imitate observed actions as a consequence of impaired inhibitory control (Lhermitte *et al.*, 1968; Luria, 1980; De Renzi *et al.*, 1996; Brass *et al.*, 2003).

Although several studies have provided evidence for a link between nonconscious mimicry and rapport (e.g. La France, 1982; Tickle-Degnen and Rosenthal, 1987; Bernieri and Rosenthal, 1991), Chartrand and Bargh (1999) were the first to show a causal relationship: Naive participants whose actions had been mimicked by a confederate during an interaction reported liking the confederate better than participants whose actions had not been mimicked. Furthermore, they also felt that the interaction had gone more smoothly. In a further experiment, the authors showed that high-perspective takers—people who have a strong tendency to take others' perspective—engaged more in nonconscious mimicry. This finding suggests that the degree to which motor resonance occurs depends on cognitive style and personality variables of the observer (see also van Baaren *et al.*, 2003, 2004). In line with this finding, a recent functional magnetic resonance imaging study by Gazzola *et al.* (2006) showed a correlation between activation in brain areas pertaining to the auditory mirror system, and perspective taking. Listening to action-related sounds, like a paper being torn apart, high-perspective takers showed more activation in premotor and parietal areas that are also active during action execution than low-perspective takers.

Further studies suggest that motivational factors also play an important role. In a study by Lakin and Chartrand (2003), participants whose goal it was to connect with another person (affiliation goal) engaged more in nonconscious mimicry, independently of whether the goal was conscious or had been activated through a priming procedure without the participants' awareness. Furthermore, participants who failed to affiliate in an interaction were subsequently more likely to mimic the behavior of a new interaction partner than those who had not failed in the previous interaction. How can one account for these findings? One possibility is that people who wish to be liked and hope to have a successful interaction pay closer attention to the other's behavior, thus increasing the likelihood of 'motor contagion'. An alternative explanation is that having an affiliation goal decreases action inhibition, thus facilitating the execution of pre-activated actions. This would imply that the threshold for inhibition can be re-set in a top-down fashion through social goals.

While nonconscious mimicry seems to play a role in enhancing mutual liking and improving the quality of interactions (Lakin *et al.*, 2003; Chartrand *et al.*, 2005), research on ideomotor movements has shown that people also mimic movements when the observed person cannot see them. This is the case when "your leg hoists itself when you're watching a high jumper on TV". Although the term 'ideomotor movement' goes back to Carpenter (1874) (see Prinz, 1987; Knuf *et al.*, 2001; Prinz *et al.*, 2005, for a historical account), the empirical investigation of ideomotor movements has only recently started to gain momentum. Importantly, studies on ideomotor movements have shown that observers' actions do not always match the perceived actions.

Knuf *et al*. (2001) used a task where people watched the outcome of their own preceding actions, much like when one has set a bowling ball in motion and watches on as it rolls toward the pins. Participants saw a ball moving towards a target on a computer screen. The trajectory of the ball was always initially defined so that the ball would miss the target. However, during the initial phase of each trial, participants could correct the ball's trajectory by moving a joystick. Once the joystick was no longer effective (second phase of each trial), participants merely watched the ball approach the target. Unbeknownst to them, during this phase, their hand movements were measured. Analysis of the movements revealed that participants unwittingly performed compensatory movements when it looked like the ball was going to miss the target (e.g. moving the hand to the left when the ball was too far to the right). Thus, movements were clearly 'intentionally induced' in that they were driven by what one would like to see happen.

The next question was, of course, whether people would also make compensatory movements when observing another's actions. De Maeght and Prinz (2004, Experiment 3) showed participants the performance of another player and asked them to track the vertical position of the ball during the second phase of the trial as it was approaching the target. This allowed them to investigate subtle horizontal movements of the joystick that participants were not aware of making. Again, they found evidence for intentional induction: when participants saw that the ball would miss the target, they performed compensatory movements, although neither they themselves nor the player whose performance they saw could affect the ball's trajectory in any way. Thus, participants performed movements that were in line with the player's intention and *should* be performed. These results suggest that action observation does not always lead to a tendency to perform the observed actions, as is generally assumed. Rather, a representation of the actor's intention can override the tendency to imitate the observed movements and lead one to perform what the other should be doing.

The current study

The studies reviewed above demonstrate that sometimes observers spontaneously imitate the actions they observe while at other times they spontaneouly produce movements that compensate for the actions they observe. What factors determine whether imitative or compensatory movements are produced during action observation? The studies above seem to suggest that compensatory actions are associated with the observation of moving objects while imitative actions are associated with the observation of moving people. Given this trend, the aim of the present study was to extend our understanding of perception–action links in social context. In two experiments, we surreptitiously measured participants' body sway as they watched short movies of an actor balancing on a wobbly foam roller and judged whether the actor would be able to walk to the end of the roller or would fall off before reaching the end (see Figure 13.1).

Experiment 1

We sought to extend the study of ideomotor movements (De Maeght and Prinz, 2004) in four ways. First, in previous ideomotor experiments, participants' movements were

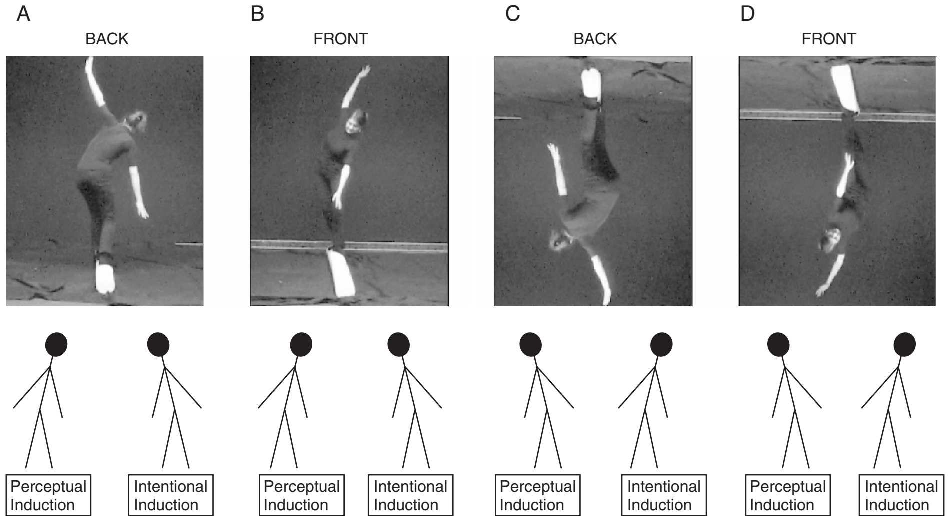

Figure 13.1 Illustration of perceptual induction and intentional induction in the upright and inverted conditions.

measured while observed actions could not be affected in any way. We think that more typically, one observes a person trying to achieve a particular action goal, rather than just observing the consequences of earlier actions. Second, in the study by De Maeght and Prinz, the task rules created a strong interest in the outcome of the observed actions because participants' score went up when the observed actor scored a goal. Here, we wanted to investigate to what extent ideomotor movements also occur in the absence of a reward associated with the action outcome. Third, it is well known that the body is a special object of perception (Knoblich *et al.*, 2006). While in previous studies only the consequences of bodily movements were shown as stimuli, we presented life-size displays of the actor's body to investigate how ideomotor movements are shaped by the perception of human motion. Finally, to investigate the role of the spatial relation between actor and observer, we included orientation as an independent variable and showed the actor from the front (different orientation) and from the back (shared orientation) in upright and inverted displays.

Predictions

There are three possible outcomes for the upright views. First, participants could show perceptual induction, moving the same way as they see the actor moving. For example, if the actor leaned slightly or dangerously far to the right, the participants should also lean to the right, even when that meant mimicking a potential fall. This would suggest that the perception of bodily movements triggers imitative tendencies, regardless of the perceived intention of the actor to avoid falling. Second, participants could show intentional induction, performing compensatory movements by leaning in the direction opposite of the actor's lean so as to 'maintain balance'. This would provide evidence for the assumption that a representation of the actor's intention, in this case, the intention to avoid falling, modulates perception–action links. Finally, the extent to which perceptual or intentional induction occurs could be modulated by orientation. When participants see the actor from the back, thus sharing the same body orientation, perceptual induction occurs when participants lean to the same side as the actor (see Figure 13.1a). For example, when the actor tilts to the right, participants should also tilt to the right. Intentional induction occurs when participants see the actor leaning to one side and lean to the other side. For example, when the actor tilts to the right, they should tilt to the left. Thus, they would be compensating for the actor and perform the kind of action she should be performing.

When participants see the front of the actor's body, perceptual induction can be defined in more than one way, because 'left' and 'right' can be coded from the observer's point of view or from the actor's point of view. We here define perceptual induction in terms of spatial direction from the observer's point of view, based on the assumption that people do not perform a mental self-rotation to imagine sharing the same viewpoint with the actor (cf. Zacks *et al.*, 1999). Thus, perceptual induction occurs for example when the actor moves to the right from the point of view of the observer (actor's upper body moves to the right side of the screen) and the observer also moves right. Intentional induction occurs when actor and observer tilt in opposite directions. For example, when the actor tilts to the observer's right, the observer leans to the left (see Figure 13.1b).

Two opposing predictions can be made for the role of orientation (front versus back). If one assumes that a shared orientation leads to greater motor resonance, participants should be more likely to perform ideomotor movements when they see the actor from the back than when they see the actor from the front. Greater motor resonance could lead to more perceptually induced movement, but could also lead to more intentionally induced movement. For example, it could be that participants are better able to simulate the observed actions when they see the actor from the back, and thus, are able to anticipate when the actor is about to fall off. This could trigger stronger intentionally induced movements. If one assumes that an actor seen from the front is usually socially more relevant than an actor seen from the back, it could also be that motor resonance is stronger when the observer sees the actor from the front. Again, this could both lead to increased perceptually induced or intentionally induced movements.

The inverted view (see Figure 13.1c and 1d) served as a control condition. Perceptual and intentional induction were again defined in terms of the participant's point of view and were based on the assumption that participants would not imagine a self-rotation to share the same orientation with the actor. From studies on the perception of biological motion, it is known that point-light-defined movements of upright bodies tend to be processed globally, while point-light-defined movements of inverted bodies tend to be processed locally (Loula *et al.*, 2005). If participants simply moved in accordance with the shifts in spatial information in the displays, the pattern of ideomotor movements should be the same for the upright and inverted displays. In contrast, if the perception of a moving body induces ideomotor movements, participants should move systematically only in the upright condition.

Method

Participants. Seventeen participants (four male, 10 female) aged between 19 and 40 years took part in the experiment as part of a course requirement. All were right-handed and had normal or corrected-to-normal vision.

Material and apparatus. Participants were presented with movies of a person balancing on a foam roller (see Figures 13.1 and 13.2). To create the movies, a female actor was videotaped (recording rate 30 frames/s) while balancing and walking along a foam roller of about 2.5 m in total length. The actor was filmed from the front and back on separate balancing attempts. From this material, 30 movies were cut using the Apple software iMovie. Half of the movies showed the actor from the front, the other half showed her from the back. The movies lasted between 5 and 10 s, with a mean duration of 7.6 s. Each movie ended once the actor had passed about half the length of the foam roller. For both the front and back view, one-third of the movies ended with the actor leaning strongly to the left, one-third ended with the actor leaning strongly to the right, and one-third ended with the actor assuming a straight position. Each movie was presented in an upright and inverted view. The inverted view was created rotating the movies by 180° using QuickTime Pro.

The movies were rear-projected onto a large screen (12 ft × 8 ft) with a Sony VPC-PX40 projector with a refresh rate of 60 Hz and a 1024 × 768 pixel resolution. The actor in the movies was displayed approximately life-sized. Picture size from the participants' position was approximately 30 × 11 visual degree horizontally and vertically. The experiment was programmed in Microsoft Visual Basic 6.0, and stimulus presentation was controlled by a Dell Pentium computer. Participants' movements were recorded using a ReActor motion capture system from Ascension Technology. The recording rate was 30 frames/s. The motion capture recording and the movie presentation were started simultaneously via remote control.

Procedure. At the beginning of the experiment, participants were asked to wear a suit specially designed for the motion capture system (see Figure 13.2). We attached motion sensors to the suit at the head, chest, upper back, and all major body joints (total of 20). Participants were told that the purpose of the experiment was to investigate how well they could make predictions about observed actions, and that the suit served to measure "how your body reacts to the movies". They were led to believe that the system captured physiological measures akin to heart rate and were not told that their movements were being recorded. Participants stood on a 1-inch-thick foam sheet that was positioned in front of the projection screen at a distance of about 3 m. They were told to keep their feet no more than hip distance apart and to assume a relaxed posture without putting all their weight on just one leg.

Each trial started with the presentation of a fixation cross presented for 1 s, followed by presentation of a movie. After each movie, participants judged on a 5-point scale whether the actor would be able to maintain her balance and continue to walk to the end of the foam roller without falling off. They were presented with the following options: "I predict that the person (1) will definitely reach the end, (2) will probably reach the end, (3) has a 50/50 chance to reach the end, (4) will probably not reach the end, (5) will definitely not reach the end." They gave their judgment by saying out loud the respective number, which the experimenter entered into the computer. The purpose of this task was to make

Figure 13.2 Illustration of the experimental set-up. For illustration purposes, the participant in this picture is standing slightly to the side. In the actual experiment, participants stood in one line with the actor in the movie.

participants look at the movies without drawing their attention to their own movements. Judgment accuracy was not evaluated because, during stimulus construction, the video-taped actor tilted her body from side to side, often dramatically while she walked along the roller, but she very rarely actually fell off. Participants watched 60 movies and were allowed to take a break after the first 30 movies. The experiment lasted about 30 min. After the experiment, participants were asked about their beliefs regarding the purpose of the experiment and were debriefed. Participants who reported being aware that their movements had been recorded ($n = 3$) were excluded from the analyses.

Design. The movies were shown in an upright and inverted view, and the actor could be seen from the front or from the back (2×2 design). Presentation of upright and inverted movies was blocked, so that half of the participants saw the inverted movies first, and half saw the upright movies first. Orientation was also blocked. Half of the upright movies started with the front perspective of the walker's body, and half with the back perspective of her body. The same was true for the inverted movies. Altogether, there were 60 trials (15 upright front, 15 upright back, 15 inverted front, 15 inverted back).

Results

The data analysis started with the specification of the direction of tilt of the observed actor's body at each point during each movie. Actor tilt was categorized as leftward whenever the actor was moving from right to left, regardless of position of the upper body relative to gravitational axis. Similarly, actor tilt was categorized as rightward whenever the actor was moving towards the right, regardless of position of the upper body from the mid line. The direction of tilt was determined through frame-by-frame visual inspection of the movies in iMovie.

To analyze participants' movements, we calculated the movement of their upper body across time, in degrees per second. The logic behind choosing a discrete measure to express the actor's movements, and a continuous measure to express the participants' movements, was as follows. First, we assumed that the respective end state of each of the actor's tilts would be critical in inducing participant's movements. Thus, the actor's movements were coded as 'leaning towards the left' and 'leaning toward the right'. Second, we chose to express the participants' movements through a spatial–temporal measure, because given the small amplitude of participants' movements, absolute values did not seem meaningful.

To calculate participants' lateral upper body movements in degrees per second, we extracted the spatial coordinates for the hips and shoulders on each frame. Specifically, we calculated the tilt of the upper body relative to the hips with a formula used to calculate the angle in a right-angled triangle where the hypotenuse and the opposite leg are known [tilt in degrees = arc-sine of (amplitude/hypotenuse)*180/P]. Amplitude was defined as the mean value of the shoulder coordinates minus the mean value of the hip coordinates on a horizontal axis, respectively. The hypotenuse was calculated as the square root of the quadrated sum of the difference between the mean value of the shoulder coordinates and the mean value of the hip coordinates (on a vertical axis, respectively) and the amplitude. Angular velocity was calculated based on the difference between subsequent frames.

Movements. Figure 13.3 shows mean angular velocity of observer body tilt in the upright (A) and in the inverted (A) condition while the actor was tilting towards the

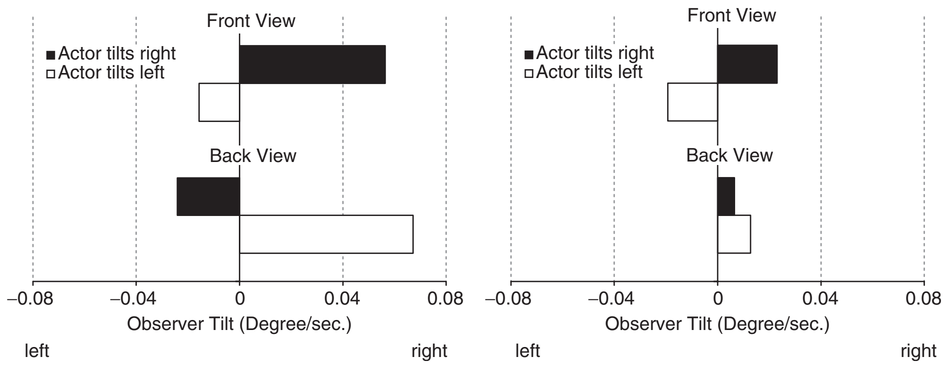

Figure 13.3 Results of Experiment 1. (**A**) Upright movies, (**B**) inverted movies. The participants' mean angular velocity (in degrees per second) is plotted across all frames in which the actor tilted rightward (black bars) and all frames in which the actor tilted leftward (white bars). Top: front view condition. Bottom: back view condition.

right or towards the left. For this analysis, we compared participants' mean angular velocity while the actor tilted leftwards or rightwards across all movies, and independent of the degree of the actor's tilt. To test for significant differences in the upright condition, a 2 × 2 within-subjects analysis of variance (ANOVA) with the factors Actor Body Tilt (left, right) and Actor Body Orientation (front versus back) was conducted. There were no significant main effects, all $p > 0.05$. Thus, whether participants saw the actor tilting towards the right or left, and whether they saw the actor from the front or from the back did not affect how much they moved overall. However, there was a significant interaction between Actor Tilt and Actor Orientation [$F(1, 13) = 9.22$, $p < 0.01$], indicating that participants' movements differed depending on whether they saw the actor from the front or from the back. When the actor was seen from the front, there was a tendency to mimic the observed movements, according to our definition of perceptual induction. Participants tilted more to the left when the actor tilted leftwards, and to the right when the actor tilted rightwards (see Figure 13.3A, upper half, and Figure 13.4A). A two-sided t-test confirmed that angular velocity was significantly different when the actor tilted left compared to when the actor tilted right [$t(1, 13) = 2.36$, $p < 0.05$]. In contrast, when the actor was seen from the back, compensatory movements occurred (intentional induction). Participants seemed to tilt more to the left when the actor tilted towards the right, and vice versa (see Figure 13.3A, lower half, and Figure 13.4B). This difference was not statistically significant, but showed a tendency [$t(1, 13) = 1.79$, $p = 0.09$]. Figure 13.3 provides an illustration of participants' tendency to mimic the actor's movements in the front condition and to perform compensatory movements in the back condition.

To test for differences in angular velocity in the inverted condition (see Figure 13.3b), a 2 × 2 within-subjects ANOVA with the factors Actor Tilt (left, right) and Orientation (front versus back) was conducted. No significant effects were observed, all p-values > 0.05. t-Tests showed that unlike in the upright condition, whether the actor was seen tilting leftwards or rightwards did not affect angular velocity [$t(1, 13) = 0.92$, $p = 0.37$ in the front view condition; $t(1, 13) = 0.11$, $p = 0.91$ in the back view condition].

Judgments. The mean judgment, along the 5-point scale, of the likelihood that the actor would fall off the roller was 3.05, SD = 0.2. t-Tests showed that the frequencies with which participants chose Judgment 2 (will probably reach the end), 3 (50/50 chance) and 4 (will probably not reach the end) were not significantly different. Judgment 1 (will definitely reach the end) and Judgment 5 (will definitely not reach the end) were chosen less frequently, all $p < 0.05$. To test for interactions between judgments, the orientation of the movies, and the perspective from which the actor was seen, a 2 × 2 × 5 ANOVA with the factors Movie Inversion (upright versus inverted), Actor Orientation (front versus back), and Judgment (1, 2, 3, 4, 5) was performed. It showed a significant interaction between Actor Orientation and Judgment [$F(4, 48) = 7.48$, $p < 0.001$], but no significant interaction between Movie Inversion and Judgment, $F(4, 48) = 1.08$, $p = 0.38$. The 'definitive' judgments (Judgments 1 and 5) were made more frequently in the front view condition compared to the back view condition, as confirmed by Newman–Keuls *post hoc* tests, all $p < 0.05$. This suggests that when participants viewed the front of the walking actor's body, they felt more certain about their judgments.

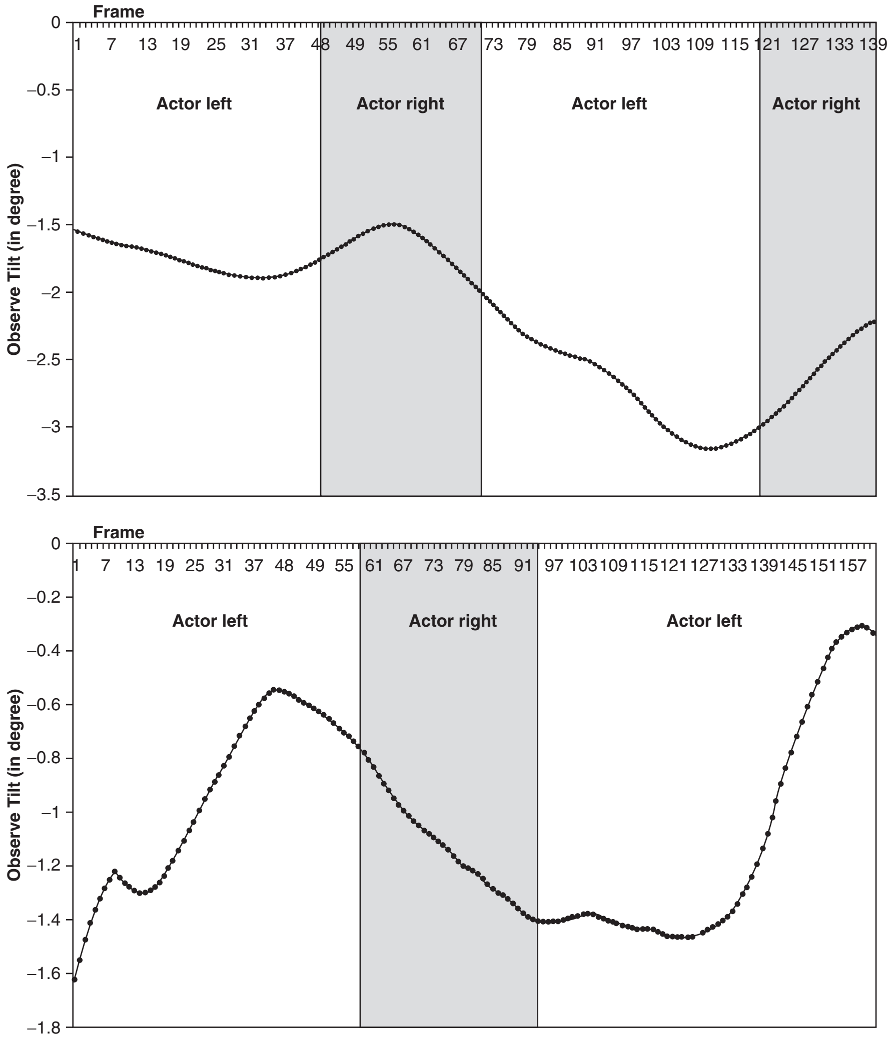

Figure 13.4 Data of one typical participant in Experiment 1. This graph shows one participant's tilt during one movie. The data were smoothed by averaging across ten frames. Higher values on the *y*-axis indicate that the participant tilted to the right, lower values indicate that the participant tilted to the left. A white background indicates the time window(s) during which the actor tilted leftward. A grey background indicates the time window(s) during which the actor tilted rightward. (**A**) Front view condition. (**B**) Back view condition.

To determine which information participants based their judgments on, we computed individual correlations between judgments and the mean tilt of the actor in each movie, as well as individual correlations between judgments and the actor's tilt at the end of each movie. The actor's tilt at the end of each movie was determined using a still frame and measuring the angle (in degrees). The mean tilt was calculated by averaging across the angles at all turning points (all maximal tilts to the left and right). If the correlation between mean tilt and judgment were stronger than the correlation between final tilt and judgment, it would mean that participants integrated information across the movies. If the correlation between judgments and the final position in the movie were equally strong or stronger, it would mean that judgments were based mainly on the final information about the actor's position.

Only participants who had given judgments from the whole range (1–5) were included in the analyses ($n = 12$). There was a significant positive correlation between mean tilt and judgments both in the upright condition ($r = 0.39$), and in the inverted condition ($r = 0.37$). There was also a positive correlation between last tilt and judgments in the upright ($r = 0.42$), and in the inverted condition ($r = 0.41$). Given that the actor's final tilt explains just as much of the variance as the mean tilt, these results suggest that both in the upright and inverted view condition, judgments were mostly based on the actor's position at the end of the movie, when the actor was closest to the end of the roller.

Discussion

The results of Experiment 1 provide evidence that ideomotor movements occur not only when the consequences of earlier performed actions are observed (De Maeght and Prinz, 2004), but are also induced by the online observation of body movements. While participants focused on making judgments about an actor's success in a balancing task, their bodies actually re-enacted and counter-acted the movements they observed. The difference between the upright and the inverted condition suggests that participants did not merely react to shifts in the spatial information in the displays, but that their movements were related to the perception of a human body moving in biologically possible ways.

Interestingly, we found a systematic relationship between the actor's and the observers' movements despite the fact that the actor's performance did not have any direct consequences for the observers. In previous studies, the experimental situation was such that observers were rewarded given particular action outcomes. Thus, it has been difficult to say whether ideomotor movements reflect the observer's hope for particular action outcomes, or whether they are of a more general nature. The present findings suggest that ideomotor movements occur in response to the perception of goal-directed actions and are not restricted to situations where the observer has a personal stake in particular action outcomes. It falls to future studies to investigate systematically the relationship between the observer's intentions and the induction of ideomotor movements. It seems likely that the tendency to perform ideomotor movements will be stronger when the outcome of observed actions has consequences for the observer or is of emotional significance.

The orientation from which the actor was seen determined the way ideomotor movements were induced. When the actor was seen from the front, perceptual induction seemed to occur: Participants moved to the side in space to which the actor's body moved. When the actor was seen from the back, intentional induction occurred. Participants leaned to the opposite side of space as the actor, thus moving in a way that was consistent with the actor's goal, but did not match the observed movements.

The results for the front view condition are consistent with findings from studies on nonconscious mimicry, which have shown that people facing each other tend to mimic each other's movements. It seems possible that a similar mechanism underlies nonconscious mimicry and the induction of ideomotor movements in face-to-face encounters. It has been claimed that the tendency to mimic others occurs because observing others' movements activates corresponding motor programs in the observer. While this tendency may remain covert most of the time, the activation of the motor system can become strong enough to override inhibitory mechanisms that normally keep us from mimicking observed actions (Wilson, 2003; Brass *et al.*, 2005). Studies on nonconscious mimicry suggest that it acts as 'social glue', increasing feelings of liking and unity. Face-to-face interactions are likely one of the standard situations where nonconscious mimicry occurs (Grammer *et al.*, 1998). It seems possible that tuning in to the other in a face-to-face interaction is so deeply ingrained that we cannot help mimicking others even when they are just actors in a movie.

One could object that the imitative movements in the front condition were due to task demands. After all, it might be easier to judge how likely the actor is to fall off when one puts oneself in her shoes and imitates her movements. Two pieces of evidence argue against such an interpretation. First, the observed movements were very small, and most participants were not aware that they had moved in response to the actor's movements. Second, if participants strategically moved in accordance with the actor, imitative movements should have been observed in the back view condition as well.

A more serious objection to the present interpretation of the results is that we cannot exclude the possibility that participants performed a mental rotation to imagine sharing the same orientation with the actor in the front view condition, or were able to map the actor's movements onto their body as if they shared the same orientation. This implies that what we consider to be imitative movements would actually be compensatory movements. This interpretation is quite appealing given its parsimonious nature. Participants clearly performed compensatory movements in the back view condition, making it tempting to speculate that intentional induction may have occurred in the front view condition as well. We cannot rule out this possibility. However, we would like to point out that previous studies suggest that participants asked to imagine the perspective from a different viewpoint have difficulties performing this imagined self-rotation and thus might not do so unasked (Wapner and Cirillo, 1968; Ishikura and Inomata, 1995; Sambrook, 1998; Zacks *et al.*, 1999; for a different perspective, see Wraga, 2003). Further studies are needed to determine whether participants do perform a mental rotation or are able to map the other's actions onto their own body when they do not share the same orientation.

The results from the back view condition are unambiguous and provide evidence for intentional induction. Participants moved the way in which the actor should move to avoid falling off. This finding is in line with previous studies of ideomotor movements, where participants always saw events unfolding from an egocentric perspective (Knuf *et al.*, 2001; De Maeght and Prinz, 2004). In these studies, participants also showed a tendency to move in the direction that corresponded to the desired outcome rather than to the observed event. But is the mechanism behind intentional induction in the present experiment the same as in these previous studies?

The compensatory movements that occur when participants observe the trajectory of a ball about to miss a target can be explained by the assumption that observers' movements are guided by an idea of what they would like to see happening. This is precisely what William James's ideomotor principle refers to. He proposed that the idea or image of a particular action will trigger the execution of this action when no conflicting mental images are present: "Every representation of a movement awakens in some degree the actual movement which is its object; and awakens it in a maximum degree whenever it is not kept from doing so by an antagonistic representation present simultaneously in the mind" (James, 1890, p. 526). In the case of intentionally induced ideomotor movements, there is actually conflicting information in the form of the events that unfold. However, it seems that the representation of imagined actions dominates and can override the visual input.

In the present experiment, observers' movements could also have been guided by an image of what the actor should be doing. However, what the actor should be doing changed from moment to moment and was not easily predictable. Although it is possible that participants put themselves in the actor's shoes and tried to imagine what she should be doing, we think it is more likely that they simply felt as if they were in the actor's place. We would like to speculate that sharing the same orientation with the actor increased the degree to which observers identified with the actor's movements. Instead of projecting themselves onto the other, the other was mapped onto the self. While this distinction may seem subtle at first, it actually points towards two different mechanisms of intentional induction.

On the one hand, observers might make compensatory movements because they want someone or something to *x*. For example, when watching a bowling ball set in motion by a team player one might move in the direction one wants the ball to roll. Thus, in this case, observers project themselves *onto* a person or object. This projection is driven by a particular goal one anxiously hopes for. Thus, in the paradigmatic situation one wishes that one was able to exert control over observed actions or events. Importantly, compensatory movements that occur as a result of wanting *x* do not necessarily rely on simulation in the observer's action system.

On the other hand, observers might make compensatory movements when they start feeling to some extent as if they were the observed. One could say that, in this case, the other gets mapped onto the self, rather than the other way round. Examples include watching someone awkwardly learning to ice-skate or trying to climb a precipice. In such cases, compensatory movements might occur because the observer's motor system has been brought to resonate with the observed movements. Sharing the same orientation and being in similar surroundings could contribute to this resonance. Importantly, according to this view, compensatory movements would occur only because the actor appears to be struggling or failing. Otherwise, imitative movements are expected. The compensatory movements would arise directly out of a simulation in the observer's motor system that indicates that the performed movements do not lead to the intended goal. Future studies are needed to validate this distinction. In the meanwhile, it is tempting to speculate that the compensatory movements observed by Prinz and colleagues are of the first kind, whereas the compensatory movements observed in the present study pertain to the latter.

Experiment 2

In Experiment 2, we aimed to replicate the finding that actor orientation modulates ideomotor movements. Furthermore, by collecting continuous movement data not only from observers, but also from the actor, we hoped to be able to further specify the nature of ideomotor movements. As a new set of balancing movies was made, the actor's movements were recorded by the same motion capture system that was used to record the observers' movements. This allows us to investigate to what extent movement characteristics of the actor can be found in the observer's motor 'echo'.

Method

Participants. Fourteen participants (three male, 11 female) aged between 19 and 41 years took part in the experiment as part of a course requirement. All were right-handed and had normal or corrected-to-normal vision.

Material and apparatus. A new set of movies was created in exactly the same way as in Experiment 1. The only difference was that this time, the actor wore the suit with sensors for movement recording. Actor movements were recorded using the same motion capture system that was used to record participants' movements in Experiment 1. The recording rate was 30 frames/s. As in Experiment 1, the actor was filmed from the front and back on separate balancing attempts. From this material, 30 movies were cut using the Apple software iMovie. Half of the movies showed the actor from the front, the other half showed her from the back. The motion capture data were edited so that the movement recordings started and ended at the same time as the movies. The movies lasted between 5 and 8 s, with a mean duration of 6.6 s. All other characteristics of the movies were the same as in Experiment 1. The apparatus used during the experiment was identical to that in Experiment 1.

Procedure. The procedure was exactly the same as in Experiment 1, except that only upright movies were shown. The experiment lasted about 30 min. After the experiment, participants were asked about their beliefs regarding the purpose of the experiment and were debriefed. Participants who reported being aware that their movements had been recorded ($n = 2$) were excluded from the analyses.

Design. Half of the movies showed the actor from the front perspective, and half from the back perspective. Presentation of front and back view movies was blocked, and the order of blocks was counter-balanced across participants. There were 30 trials (15 front, 15 back).

Results

The data of two participants had to be discarded due to problems with the movement recording, so the data of 10 participants were analyzed. One of the movies showing the actor from the front had to be excluded from the analysis because it turned out that there had been problems with the movement recording of the actor.

In a first step, we analyzed the results in exactly the same way as in Experiment 1. Thus, we classified whether the actor moved towards the left or towards the right and averaged the participants' movements across all instances where the actor moved leftwards or rightwards. We used the actor's motion capture data (tilt calculated in the same way as in Experiment 1) to classify movements as leftwards and rightwards. As can be seen in Figure 13.5, the pattern of results looks similar to the results observed in the upright condition in Experiment 1. To test for differences between the two experiments, a $2 \times 2 \times 2$ ANOVA with Experiment as a between-subject variable and Actor Orientation (back, front) and Actor Tilt (left, right) as within-subject variables was conducted. There was a significant main effect of Experiment [$F(1, 22) = 10.79$, $p < 0.01$]. Participants' movements were more pronounced in Experiment 2 than in Experiment 1. Again, participants had a general tendency to move to the right. Importantly, the interaction between Actor Orientation and Actor Tilt was significant [$F(1, 22) = 6.45$, $p < 0.05$]. No further significant effects were observed, suggesting that overall, a similar pattern was found in both experiments (see also Figure 13.6).

There were some differences between the front and back condition in the two experiments, however. Unlike in Experiment 1, a two-sided *t*-test comparing angular velocity when the actor tilted leftwards compared to when the actor tilted rightwards in the front view condition was not significant, $p > 0.05$. However, there was clear evidence for compensatory movements when the actor was seen from the back. Participants tilted more to the left when the actor tilted rightwards, and vice versa [$t(1, 9) = 4.06$, $p < 0.01$].

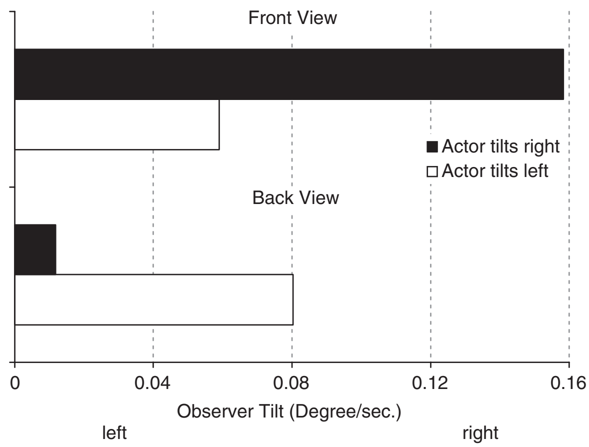

Figure 13.5 Results of Experiment 2. The participants' mean angular velocity (in degrees per second) is plotted across all frames in which the actor tilted rightward (black bars) and all frames in which the actor tilted leftward (white bars). Top: front view condition. Bottom: back view condition. Note that the *x*-axis label was kept the same as in Figure 13.3, but participants on average did not move to the left of the mid line.

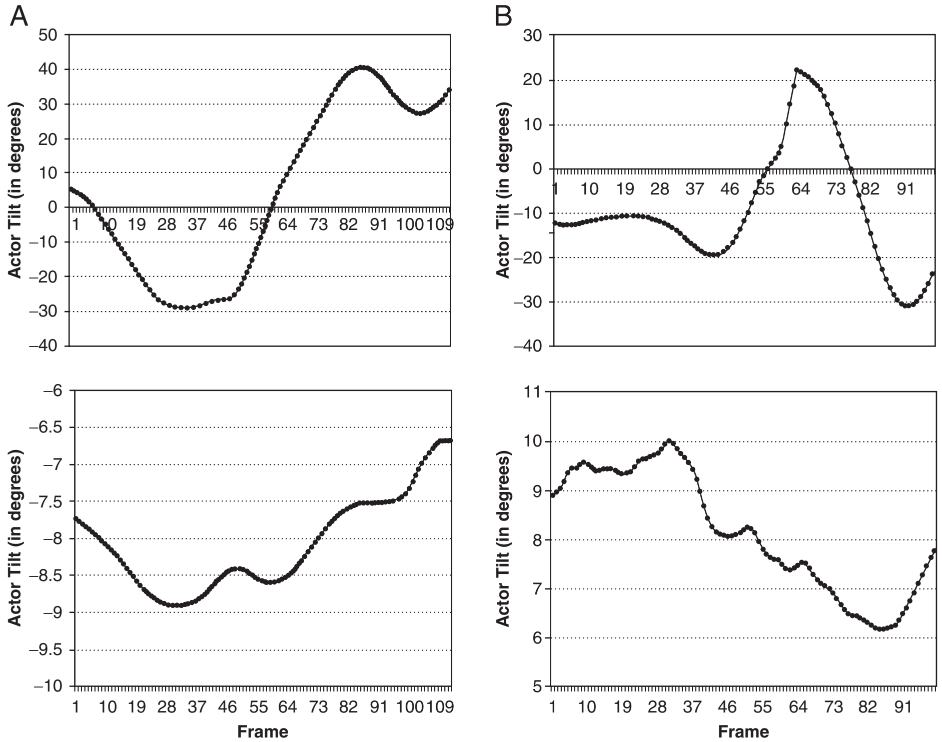

Figure 13.6 Data of the actor and one typical participant from Experiment 2. (**A**) Front view condition. (**B**) Back view condition. Upper panels: Actor. Lower panels: Participant. The actor's and the participant's data were smoothed by averaging across ten frames. Higher values on the *y*-axis indicate rightward movements and lower values indicate leftward movements.

To address the question of whether the amplitude of the actor's movements (how much the actor tilted to the side) had an impact on ideomotor movements, we calculated the mean standard deviation of the actor's tilt (in degrees) per movie and correlated this with the mean standard deviation of each observer's tilt during presentation of each movie. The actor's tilt was calculated in the same way as the participants' tilt (see Experiment 1 for details). In the front view condition, the average correlation coefficient was close to zero ($r = 0.07$), in the back condition it was slightly higher ($r = 0.21$). However, this difference was not significant [$t\,(1, 9) = 1.23, p = 0.25$].

Discussion

Experiment 2 replicated the finding that actor orientation modulates ideomotor movements. Participants seemed to mimic the actor's movements when the actor was seen from the front, and performed compensatory movements when the actor was seen from the back. Contrary to Experiment 1, the compensatory movements in the back view condition were more pronounced, while the tendency to imitate the observed movements was weaker. Overall, participants tended to move more to the right. Analyses of the movies in Experiments 1 and 2 showed that in both experiments, the actor moved approximately an equal amount of time to the left and to the right, so it seems unlikely that participants' general tendency to lean to the right was due to the observed movements. However, there could be a connection between participants' right-handedness and their tendency to move to the right.

Analysis of the movement amplitudes did not show a correlation between the amount to which actor and observer tilted sideways. It seems possible that ideomotor movements do not reflect the extent to which observed actions 'go wrong', but rather occur whenever the success of performed actions is perceived as questionable. Previous studies have not analyzed ideomotor movements in such a fine-grained way. It could be a promising endeavour for future studies to investigate the relation between observers' intention and the similarity of movement characteristics of observed and performed movements.

General discussion

The study of ideomotor movements is a challenging endeavour, because in everyday life, ideomotor movements usually occur as single instances in response to highly specific situations. With the present paradigm, we were able to induce consistent ideomotor movements. Orientation modulated the way in which observers unwittingly moved: when the actor was seen from the front, participants seemed to mimic the observed movements, whereas when the actor was seen from the back, they performed compensatory movements.

One could argue that it was not orientation alone that modulated observers' movements, but also the movement direction of the actor. In Experiments 1 and 2, orientation and movement direction were confounded such that in the front view condition, the actor always moved closer to the observer, whereas in the back view condition, the actor moved away from the observer. It seems unlikely that movement direction alone would induce different patterns of ideomotor movements, but on the basis of the present study, we cannot rule out the possibility that direction also played a role. This could be investigated in future studies by manipulating orientation and movement direction independently of one another. For now, we would just like to note that the change in distance between actor and observer was not very pronounced in our experiments, because actors only moved a short way along the balancing beam.

In the following, we will discuss in more detail which mechanisms might give rise to ideomotor movements. As we suggested earlier, an important dimension along which ideomotor movements could be characterized is intentionality. Prinz and colleagues distinguished between perceptually induced and intentionally induced ideomotor movements. This distinction implies that people move in response to observed actions or events either because they hope for a particular outcome (intentional induction) or simply because, due to close links between action perception and action execution, the observation of an action creates a tendency to perform this action (perceptual induction). However, movements one would typically interpret as intentionally induced could still result from different processes. They could either reflect an urge to exert control over the observed event (such as when one wishes one could give the soccer ball a little spin to push it into the goal), or they could reflect a kind of 'over-identification' whereby one feels as if one were in the place of the observed rather than the observer and thus start moving accordingly. Meyer and Hobson (2005) have also described this phenomenon as a process of assuming another's stance, whereby "actions and attitutes anchored in the other person's bodily located orientation towards the world become assimilated to the individual's own bodily located orientation" (p. 225).

One important difference between these two mechanisms is the contribution of the observer's action system. While the 'control urge' type of intentional induction does not imply resonance in the observer's motor system, the 'projection' kind of induction is assumed to occur because similar motor programs are activated in the actor and in the observer. Thus, it seems likely that ideomotor movements of the first kind will occur primarily in response to objects, while ideomotor movements due to motor resonance might be primarily associated with the perception of human action. One could assume that due to motor resonance, visual information about the other's movements is treated as feedback about one's own actions.

According to the internal model theory of control, we normally guide and control our actions by comparing predicted with actual sensorimotor consequences of our actions (Wolpert and Kawato, 1998; Frith *et al.*, 2000). It could be that due to a tight coupling between perception and action, the prediction of sensorimotor consequences is no longer based on one's own actions, but based on the observed actions. By running simulations of the other's movements in one's own action system, the sensory consequences of moving in the observed way are predicted (Wilson and Knoblich, 2005). When a monitoring process signals that the planned movements will not lead to the desired outcome, this will automatically result in adjustments, reflected in compensatory movements.

If the account described above is correct, it follows that anything that will increase motor resonance and thereby simulation processes in the observer will lead to a stronger tendency to perform ideomotor movements. Sharing the same orientation as another person is a good candidate for increasing motor resonance, because it it easier to map someone's movements onto one's own body when the orientation is the same. Another interesting prediction that follows is that experts in a particular action domain might have a stronger tendency to perform ideomotor movements than novices. It has been shown that the greater one's expertise in a particular action domain, the greater the neural activation in the motor system (Calvo-Merino *et al.*, 2005; Cross *et al.*, in press). In a study by Calvo-Merino *et al.* (2005), ballet dancers showed more activation in areas of the human mirror system when watching movies of someone dancing ballet compared to movies of someone dancing capoeira, whereas the opposite pattern was observed for capoeira dancers. Accordingly, one could predict that gymnasts observing someone engaged in a tricky balancing task might show more ideomotor movements than novices, because motor resonance is increased.

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Another interesting question is whether the ability to put oneself in someone else's shoes to predict their feelings, beliefs, and intentions—known as theory of mind (ToM)—bears any relation to these highly automatic phenomena of resonance. Many authors have speculated that the mirror system might be a precursor to, or even provide aspects of, theory of mind (e.g. Gallese and Goldman, 1998; Gallese *et al.*, 2004). It has also been claimed that the mentalizing difficulties observed in people with autism might be connected to a mirror system deficit (e.g. Williams *et al.*, 2001; Gallese, 2003). While some studies have provided evidence for this claim (Nishitani *et al.*, 2004; Oberman *et al.*, 2005; Théoret *et al.*, 2005), it still remains to be determined whether the mirror system deficit observed in autism is a primary dysfunction or a result of dysfunction in other brain areas (Oberman *et al.*, 2005), and whether there is a causal relationship between the mirror system deficit and impairments in theory of mind. Nevertheless, it is worth considering how a mirror system deficit would affect the production of ideomotor movements.

If one assumes that individuals with autism have a mirror system deficit, they should show less ideomotor movements than healthy controls in our balancing paradigm. Based on findings by Théoret *et al.* (2005), one could even speculate that they would move less in particular when the orientation is shared with the actor. In the study by Théoret *et al.*, muscle-specific facilitation during action observation was absent in individuals with autism specifically when the actions were seen from an egocentric perspective. Thus, in our paradigm, fewer ideomotor movements would be expected especially in the back view condition. In contrast, when individuals with autism observe objects rather than human agents and want the object to *x*, 'control-urge' type of ideomotor movements should still be observed. Thus, one should see the following dissociation: People with autism should move less when they see someone balancing, but just as much as healthy controls when they see a ball missing a goal. This prediction remains to be tested in future studies. Note that similar predictions also follow from the more general view that individuals with autism have a deficit relating self to other (Barresi and Moore, 1996; for an overview, see Meyer and Hobson, 2005).

We would like to conclude this paper with some more general remarks on the nature of bodily bonds between self and other. While some may be sceptical about the 'mirror neuron hype' that cognitive neuroscience has seen in past years, it seems obvious that now that there is extensive behavioral, neurophysiological, and brain-imaging evidence for a close link between action observation and action execution, we must go on to find out what functions these close perception–action links have. Much points towards social functions (Knoblich and Sebanz, 2006), ranging from action understanding (Rizzolatti and Craighero, 2004) and the predictions of other's actions (Wilson and Knoblich, 2005) to establishing feelings of rapport and liking (Lakin and Chartrand, 2003). It might be useful to distinguish between convert and overt imitation phenomena and ask whether these have similar or different purposes.

One could speculate that while covert simulation is related to action understanding and action prediction, overt simulation is related to the establishing of interpersonal bonds. Nonconscious mimicry has been shown to enhance mutual liking, and is even used as a tool to overcome ostracism and create bonds with others. While research on nonconscious mimicry has focused on postural similarities between people, one should not lose sight of other perception–action coupling processes that might contribute to social interactions. A range of studies has shown that people have a tendency to entrain, be it swinging pendulums in synchrony despite the instruction to keep one's own pace

(Richardson *et al.*, 2005) or sitting next to each other in rocking chairs and moving in synchrony despite different eigenfrequencies of the chairs (Goodman *et al.*, 2005). Interestingly, coupling of body sway was found even between people who could not see each other but were engaged in a conversation (Shockley *et al.*, 2003), and there is evidence for close couplings between speakers' and listeners' eye movements (Richardson and Dale, 2005). It remains to be seen whether common mechanisms can be postulated for these different kinds of perception–action links, and how they contribute to so-called 'higher' cognitive functions. So far, we can conclude that people have a strong tendency to use their bodies to create social bonds, and that social context creates different affordances for this bodily bonding. Ideomotor movements may reflect a spill-over of the motor resonance that contributes to action understanding, prediction, and bonding in social interactions.

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