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## Action during body perception: Processing time affects self–other correspondences

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The accurate perception of other people and their postures is essential for functioning in a social world. Our own bodies organize information from others to help us respond appropriately by creating self–other mappings between bodies. In this study, we investigated mechanisms involved in the processing of self–other correspondences. Reed and Farah (1995) showed that a multimodal, articulated body representation containing the spatial relations among parts of the human body was accessed by both viewing another’s body and moving one’s own. Use of one part of the body representation facilitated the perception of homologous areas of other people’s bodies, suggesting that inputs from both the self and other activated the shared body representation. Here we investigated whether this self–other correspondence produced rapid facilitation or required additional processing time to resolve competing inputs for a shared body representation. Using a modified Reed and Farah dual-task paradigm, we found that processing time influenced body-position memory: an interaction between body-part moved and body-part attended revealed a relative facilitation effect at the 5 s ISI, but interference at the 2 s ISI. Our results suggest that effective visual-motor integration from the self and other requires time to activate shared portions of the spatial body representation.

The accurate perception of other people and their postures is essential for functioning in a social world. Recently researchers have taken an embodied approach to social perception, emphasizing how we use our own bodies to perceive others as well as determine their intents and emotions (e.g., Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005; Reed & Farah, 1995; Reed & McIntosh, 2007). Our own bodies organize information from others to help us respond appropriately. Humans have specialized body-processing mechanisms and representations that form the fundamental self–other correspondence from which social-emotional processes may be based (Jacobs & Shiffrar, 2005; Reed, 2002; Reed & Farah, 1995; Reed, Stone, Bozova, & Tanaka, 2003; Reed, Stone, Grubb, & McGoldrick, 2006a; Reed, Stone, & McGoldrick, 2006b). In this paper

we investigate mechanisms involved in the creation of self–other correspondences.

To achieve successful social interaction, substantial amounts of information must be quickly processed about the relation between the one’s own intents and those of others (Barresi & Moore, 1996; Moore, 2006). That other people have intentions and the ability to perform actions adds to processing loads and constrains our own actions in the environment. As a result, our cognitive systems must provide an efficient way for self–other correspondences to be constructed. One way to establish the commonalities between the self and other may be through processes and representations attuned to human body structure and biomechanics (Reed et al., 2003; Reed et al., 2006a; Shiffrar, 2006; Wilson, 2001, 2005; Wilson & Knoblich, 2005).

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Much of social perception requires an assessment of how much another person is “like me.” Unlike the majority of objects that we encounter in our lives, visually perceived body postures and actions of other people can be directly mapped onto and reproduced by our own body (Bertenthal & Pinto, 1994; Wilson, 2001). Further, neuroimaging research suggests that the brain provides a special status to perceptual stimuli that correspond to one’s own body (Blakemore, 2006; Downing, Jiang, Shuman, & Kanwisher, 2001; Grossman, 2006; Saxe, Jamal, & Powell, 2006). We can identify other humans, as humans, because they possess both a human body that is similar in structure to ours and that can make similar expressions, postures, and movements. Research in body perception emphasizes the importance of self–other correspondences in the perception of others. Structural similarity between one’s own body and another’s provides information regarding commonalities in the spatial layout of body parts and permits inferences regarding the body’s biomechanics with which one can determine whether one’s own body could perform similar movements (Meltzoff & Moore, 1995; Rizzolatti & Craighero, 2004; Wilson, 2001). Thus, the similarities between another person’s body and our own permit visual and proprioceptive inputs from both bodies to be represented in a common representation.

At the core of self–other mapping is the long-term body representation that contains the basic spatial layout and biomechanics of the human body. Neuropsychological, developmental, and behavioral studies have provided evidence for a central, spatial, body-specific representation that is spatially organized, supramodal and used for representing other bodies as well as one’s own (Buxbaum & Coslett, 2001; Gallagher, 2005; Reed, 2002; Reed & Farah, 1995; Schwoebel, Buxbaum, & Coslett, 2004). Patients with autotopagnosia cannot locate body parts on themselves or others despite demonstrating knowledge of bodies, naming of body parts and relatively intact spatial abilities (DeRenzi & Scotti, 1970; Ogden, 1985; Sirigu, Grafman, Bressler, & Sudnerland, 1991). Further, such deficits are found for both visual and tactile localization (Ogden, 1985).

Developmental research indicates that this body representation serves to integrate and process stimuli across sensory modalities, even in infancy. When adults model gestures such

as mouth opening, tongue protrusion and lip protrusion, newborns are able to copy them (e.g., Abravanel & DeYong, 1991; Meltzoff & Moore, 1977, 1989, 1995, 1997). The ability of infants to view another person’s movements and reproduce them with their own bodies indicates that infants have a representational system of the body that links the actions of the self (proprioception) to the actions of another (vision) via supramodal or cross-modal integration (Meltzoff & Moore, 1995).

The adult behavioral literature supports this idea. Reed and Farah (1995) was one of the first studies to demonstrate a self–other, visual–motor interaction in memory performance. In a dual-task paradigm, the primary task was a body-position memory task: participants viewed a human model in an abstract posture, followed by a 5 s blank ISI, and then viewed the model again from a different angle; participants determined whether the two postures were the same or different. To ensure that participants were focused on specific body regions, prior to each trial participants were validly cued to focus on either the arm or leg positions because any postural changes would occur in that region. While performing the primary *visual memory* task, participants performed a concurrent *movement* task: they were instructed to move their arms or legs in a series of self-selected, non-repetitive body positions that could not match the memory-task’s posture. Evidence that both visual body perception and body movement drew on a common spatial body representation or body schema (i.e., a spatial representation specific to the body) came from the interaction between the viewed model’s body part and the participant’s moved body part. The body-part-specific interaction indicated that memory for the position of the specific body part was relatively *improved* by the movement of the *same* body part. For example, arm movement improved memory for the model’s arm position relative to memory for the model’s leg position and/or it was relatively better than its recognition during leg movement.

Reed and Farah (1995) attributed this relative facilitation effect in terms of visual and motor inputs activating the same, or shared, portion of the long-term body representation (i.e., the body schema) in memory, thereby selectively aiding memory for limb position in that body region. This finding is specific to bodies because when the primary task was changed to test memory for

upper and lower regions of abstract objects, movements of the arms or legs did not influence participants' object configuration memory for corresponding regions. Further, these facilitory effects could not be attributed to imitation. When participants matched one part of their body to the remembered position and moved the other part, body-part memory selectively improved for the moving parts, not the imitating parts. Thus, the same body representation was used to encode the body positions for the self and others.

Nonetheless, the mechanism for creating self–other correspondences remains unclear. Most researchers agree that concurrent visual and motor inputs access a common representation (e.g., Decety, 2002; Decety & Grezes, 1999; Prinz, 1997; Reed & Farah, 1995; Shiffrar & Freyd, 1993; Wilson, 2001). Evidence for this comes from a variety of studies including manual and mental rotation of objects tasks (Wohlschläger & Wohlschläger, 1998; Parsons, 1987a,b), sensorimotor dual-task paradigms (Jacobs & Shiffrar, 2005; Prinz, 1997; Reed & Farah, 1995; Viviani, 1990; Viviani & Stucci, 1992), apparent biological motion (Heptulla-Chatterjee, Freyd, & Shiffrar, 1996; Shiffrar & Freyd, 1990, 1993), and even single-cell recording paradigms in mirror neurons in premotor and parietal cortices (Graziano, 1999; Rizzolatti, Fadiga, Gallese & Fogassi, 1996). However, researchers do not agree on the consequence of accessing a common representation and its time course.

In this paper, we propose two different models to address self–other mappings and the integration of concurrent visual and motor inputs into a common body representation. The facilitation model proposes that concurrent visual and motor inputs activate similar portions of the common representation to facilitate processing. Facilitated body processing from concurrent visual and motor inputs is supported by a number of studies including Jacobs and Shiffrar (2005), Viviani & Stucchi (1992), as well as Reed and Farah (1995). Nonetheless, these studies do not address the effects of processing time required for facilitated processing.

Some research from mimicry and imitation literatures suggests that self–other correspondences occur rapidly. For example, mimicry is thought to be a rapid, automatic process that leads to the matching of facial expressions, vocal tones, postures, and movements of others within milliseconds (Hatfield, Cacioppo, & Rapson, 1994; Moody & McIntosh, 2006). This mirroring

or mimicry of others is socially relevant because it may provide means by which we use our own body and face to gain information about another person. Further, the matched facial or bodily position or movement between the self and others can then initiate or modify emotional feelings in a person (Adelman & Zajonc, 1989; McIntosh, 1996), which may in turn cause the observer to feel what the observed person is feeling. It is possible that mirror neurons aid this rapid process (e.g., Gallese, 2004). However, it is an open question regarding the extent to which these processes are involved in tasks for which matching one's body to the to-be-remembered stimulus is not permitted.

The common code model links visual perception and action in self–other mappings, but with different consequences. The common code model (e.g., Prinz, 1990, 1997; Hommel, 1997) proposes that perceived and executed actions rely on similar cognitive representations, but that these shared representations lead to inhibition and impaired performance (Bekkering, 2002; Kerzel, 2001; Prinz, 1997, 2002; Schuböe, Aschersleben, & Prinz, 2001; Wohlschläger & Wohlschläger, 1998). In other words, concurrent visual and motor inputs compete for the same action representation, at least initially. Some recent research suggests that this competition can resolve itself with processing time (e.g., Schuböe, Prinz, & Aschersleben, 2004).

In the current study, we investigate mechanisms underlying the integration of concurrent visual and motor inputs into a common, spatially-organized body representation. We can contrast the two models by manipulating the processing time for concurrent visual and motor inputs in a modified Reed and Farah (1995) dual-task paradigm. This paradigm was selected because the body-part-specific interaction indicates the integration of visual and motor inputs into a common body representation. The direction of the interaction can indicate relative facilitation or inhibition of body-position memory. The processing-time manipulation not only distinguishes the two theories but it also has been shown to influence the existence of body-specific effects in apparent motion paradigms of body movement: increased processing time changes the visual perception of arm movement from moving in the shortest path of motion through the body to moving in longer, anatomically appropriate motion paths around the body (Shiffrar & Freyd, 1993).

Thus, there are two basic predictions related to the creation of a self-other mapping and to the consequences of that mapping. First, if self-other mappings occur rapidly and potentially automatically, then a significant body-specific interaction between body-part moved and body-part viewed should be found for both experiments and processing time intervals. Second, however, the consequences of this self-other mapping differ for the two models. The facilitation model would predict that body-part-specific interactions should occur in the direction of facilitated performance for any concurrent visual and motor inputs, regardless of processing time. In contrast, the common code model would predict that the body-part-specific interactions should disappear or show an interaction in the direction of decreased performance, especially for shorter processing times when concurrent visual and motor input compete for the same portion of the spatial body representation. Experiment 1 replicates the 5 s ISI of the Reed and Farah (1995) experiment using the modified paradigm. Experiment 2 uses a 2 s ISI to investigate potential consequences of decreased processing time on body-position memory. Last, Experiment 3 tests whether movement is needed to produce the body-specific interaction or whether mirror neurons can produce the interaction from two concurrent visual body-position memory tasks.

## EXPERIMENT 1

The purpose of Experiment 1 was to replicate Reed and Farah's (1995) results of a body-part-specific interaction pattern consistent with relative facilitation: use of one part of the body schema facilitated the perception of homologous areas of other people's bodies. This outcome is consistent with both models if the common code model is allowed to resolve the competition between visual and motor inputs with sufficient processing time. Two modifications were made to the Reed and Farah (1995) paradigm. First, computer-generated 3D body stimuli were substituted for real-person videotape stimuli. This permitted greater control of the distinctiveness among poses. Second, the secondary movement task was altered. Instead of generating their own sequence of non-repetitive positions, participants moved to match their body positions to a series of body positions presented visually on a second computer screen (see Figure 2). This modification

required participants to access the body schema and update their current body positions, but at the same time it ensured that participants did not match their body positions to those of the viewed model. It also controlled for the rate of movement across participants.

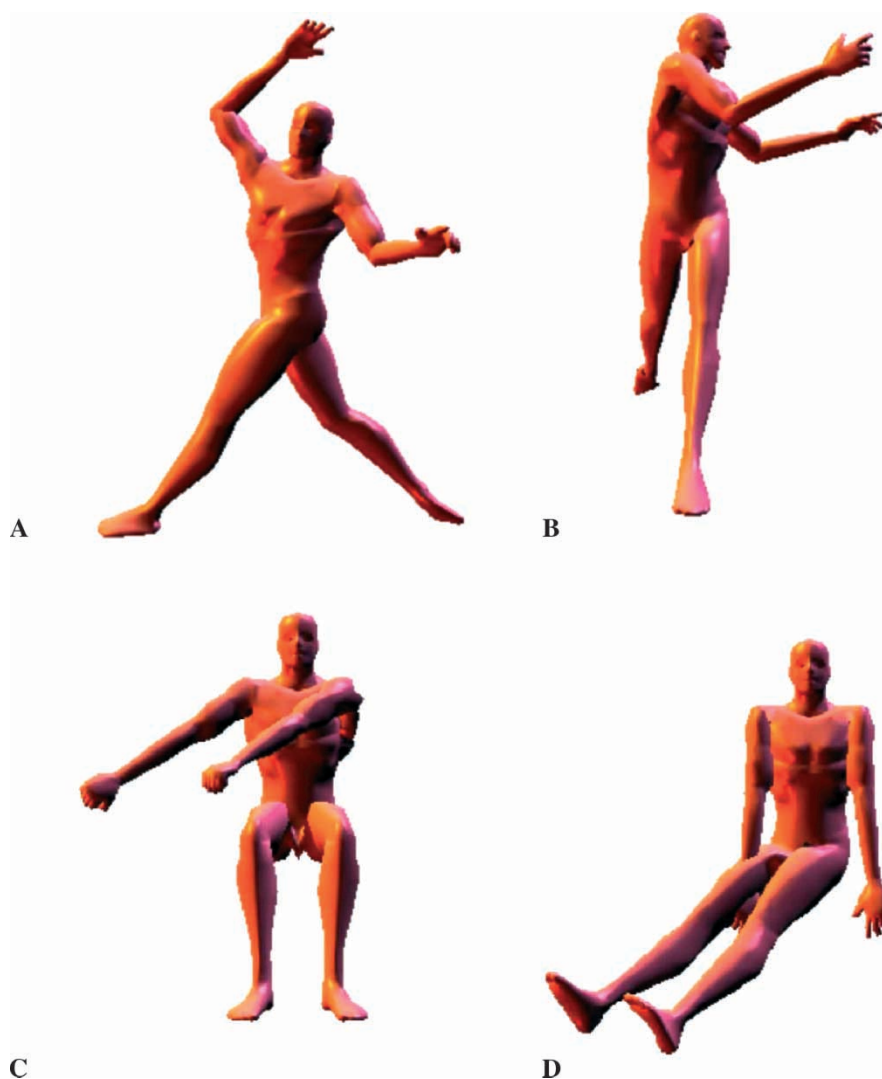
## Method

*Participants.* Twelve undergraduates from the University of Denver participated for extra course credit in psychology courses. All participants had normal or corrected-to-normal vision.

*Stimuli and apparatus.* The stimuli, design, and procedure were modeled after Reed and Farah (1995). Stimuli were presented on two Macintosh 15" color monitors, with 640 × 480 pixel resolution via Psyscope<sup>©</sup> software for the Macintosh. A Power Macintosh 7100 computer was used to create the stimuli and control the experiment presentation. The body stimuli were 3D male figures created using Fractal Design Poser<sup>™</sup>. Although the model body from which the poses were constructed was constant in size, the outer envelope of the body stimuli varied slightly with the different positions. On average, stimuli were 7 cm wide and 10 cm tall. Participants viewed the stimuli at a distance of approximately 40 cm. The figure's arms and legs were positioned to create novel poses that were visually distinguishable from each other, had no meaningful posture, and could not be easily labeled. The poses were asymmetrical with respect to both vertical and lateral body axes.

For the primary memory task, 20 stimulus pairs were constructed. One member of the pair, the memory pose, was oriented directly towards the viewer, and the other member, the target pose, was rotated 90 degrees to the left. The viewing angle was changed to encourage participants to form a 3D spatial representation of the body configuration. Half of the target stimuli were identical to the paired memory pose and half were different from the memory pose. The "different" target poses differed in terms of arm position or leg position, but not both (see Figure 1, Panels A and B). Position changes involved altering the angle of either the arms or the legs, keeping other body parts the same.

For the secondary task, eighteen additional body-guide stimuli were constructed. Poses were selected so that no body position matched any other body position in either the primary or the



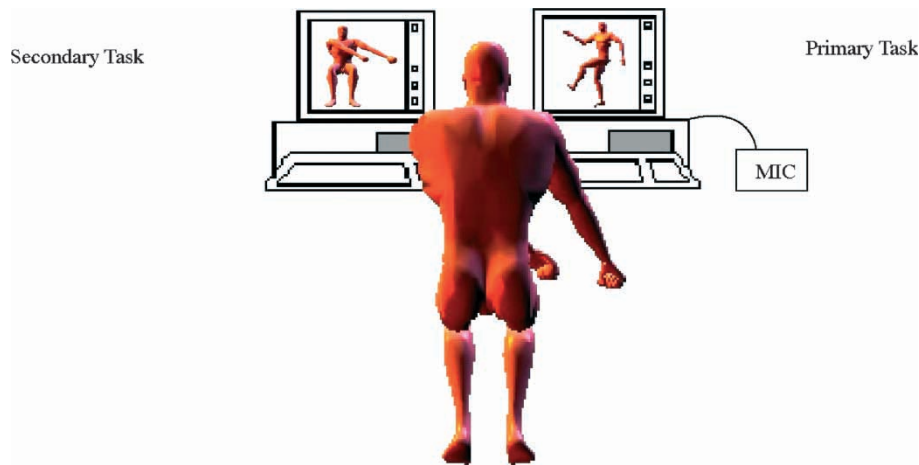
**Figure 1.** Examples of stimuli used in the primary and secondary tasks of Experiments 1 and 2. Body stimuli used in the primary memory task. Panels A and B demonstrate the changes in body posture characteristic of a “different” trial. Panels C and D illustrate arm and leg position stimuli for the secondary-movement tasks.

secondary tasks. Half of the secondary body stimuli depicted the male figure with neutral arms (i.e., held at the side) and posed legs. The other half depicted the male figure with neutral legs and posed arms (see Figure 1, Panels C and D). Participants used these stimuli to position their own arms or legs to match the arm or leg positions of the body-guide.

*Design and procedure.* Participants engaged in two tasks concurrently: a primary memory task and a secondary movement task. The primary task was a body-position memory task. Participants viewed human-like figures posed in static body positions. During each trial, a memory pose was presented for 4 s, followed by a 5 s blank

screen (ISI), and a target pose. The 5 s ISI replicated Reed and Farah (1995) that produced the original relative facilitation effect. Participants were to determine if the target pose was different from the memory pose. Judgments were made without respect to angle rotation of the stimulus figure. The target pose remained on the screen until the participant made a vocal response of “same” or “different.” The experimenter recorded the response, but provided no feedback.

Before each trial, the experimenter verbally cued participants to focus on either the model’s arm or leg position in the memory pose (either “arms” or “legs” was stated). The cues were 100% valid, and an equal number of arm and leg



**Figure 2.** The dual-task experimental set up used in Experiments 1 and 2. Stimuli for the primary task were presented on the computer screen on the right. Stimuli for the secondary task were presented on the computer screen on the left. In this example, participants matched their own arm positions to a series of model's arm positions on the left screen. Participants were told to remember the body position of the model on the right screen.

cues were randomized throughout each block. Thus, the rational strategy was to attend to the cued region of the model's body; if the memory pose changed, it would occur only in the cued body region. Since the attended region of the memory pose is known, the complete data set can be used in the statistical analyses. The cueing of attention to the figure's body region provides the basis for the interaction between the participant's body part moved and the model's body part attended.

For the secondary movement task, participants' movements were guided by a series of eight static body postures depicted by a model on a second computer monitor, located to the left of the primary task monitor. They either matched their arm or leg positions to the model's arms or leg positions, respectively. Each of the eight body guides was presented for 1.5 s. The onset of the secondary movement task was presented simultaneously with the onset of the memory pose in the primary task. For every trial, eight guides were presented randomly with replacement from the larger set of 18 body guides. Participants were instructed to maintain movement through the ISI duration and to respond to the target pose in the primary task as soon as it was presented.

The experimenter made sure that each participant understood the instructions. Participants were monitored by the experimenter for the accuracy and timing of their positions relative to the body-guides, but none had difficulty understanding the instructions or performing the tasks. Figure 2 depicts the dual-task experimental set

up. All participants sat in a large chair centered between the two displays. After the body-part cue was announced, participants began performing the primary and secondary tasks simultaneously. They continued until they made a verbal response for the primary task.

Before each block of trials, participants completed three practice trials. Experimental trials followed in which there were six blocks of 40 trials each, for a total of 240 trials. Participants received one block of randomized trials in which arm movements were performed and another block where leg movements were performed. The order of limb movement was blocked and counterbalanced across participants. Participants were given a rest period between each block of trials. The complete experiment lasted approximately 45 minutes.

## Results and discussion

Proportion error was calculated for each cued body region in each moved body part for each ISI condition. No participants were at ceiling performance. In addition, no participants exceeded a 35% error-rate criterion. This limit ensured that body-specific responses were not driven by chance performance. Although these criteria restrict our ability to fully differentiate individual means, they are necessary to increase our ability to interpret the interaction. All participants' data were included in the subsequent analyses. An item analysis for performance on the primary task

during the dual task revealed that errors were distributed consistently over the trials, and that no single item produced a disproportionate number of errors. Alpha was set at .05.

A Body Part Moved (arms, legs)  $\times$  Body Part Cued (arms, legs) ANOVA was conducted on percent error data. There were no significant main effects of body part moved,  $F(1, 11) < 1$ , or body part cued,  $F(1, 11) < 1$ . Of interest was the significant interaction between Body Part Cued and Body Part Moved,  $F(1, 11) = 7.05$ ,  $p < .05$ . This body-part-specific interaction replicated Reed and Farah (1995) and indicated the creation of self–other correspondences. The direction of the interaction was consistent with relative facilitation (see Figure 3). Performance on the primary memory task was relatively more accurate when the participant moved the same body part he/she was cued to remember of the model's pose. Although the direction of the means were consistent for both limb movement groups, post hoc contrasts were only significant when participants moved their legs as they made more errors when cued to the model's leg region than when cued to the arm region,  $F(1, 11) = 6.72$ ,  $p < .025$ . In sum, the participant's own movement and the visual perception of another's body position concurrently activated similar portions of the spatial body representation and led to relatively facilitated performance.

## EXPERIMENT 2

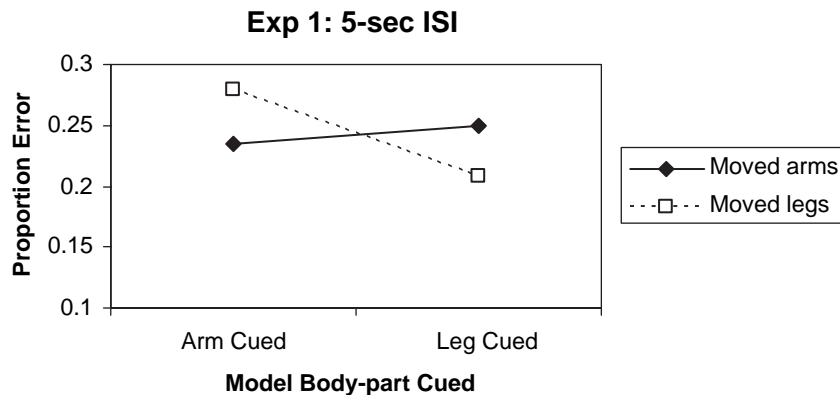
The purpose of Experiment 2 was to determine whether processing time influences the creation of

self–other correspondences and the consequences of visual–motor integration. In this experiment, the ISI was shortened to 2 s. The 2 s ISI was selected because pretesting indicated that it was the shortest ISI that would permit a series of body positions to be assumed in the secondary task. If visual and motor inputs activate a common region of the shared body representation and this effect is always facilitatory, then a body-part-specific interaction should be found at the 2 s ISI that indicates a relative increase in body-part memory. However, if visual and motor inputs compete for the shared portion of the spatial body representation, then either a body-part-specific interaction should be found that indicates a relative decrease in common body-part memory or no interaction should be found.

## Method

*Participants.* Forty-one undergraduates from the University of Denver participated for extra course credit in psychology courses. All participants had normal or corrected-to-normal vision.

*Stimuli, design and procedure.* The stimuli, design, and dual-task procedure were the same as Experiment 1 with one exception: the ISI between the memory and target poses in the primary memory task was shortened to 2 s. The same design and procedure were used for Experiment 2 as for Experiment 1. Participants were monitored for accuracy. Each participant received one block of 40 trials with arm movement and a second block of 40 trials with leg



**Figure 3.** Experiment 1. With a 5 s ISI, a significant body-part-specific interaction (i.e., the Body Part Moved  $\times$  Body Part Cued interaction) was found that revealed relatively better performance when the same body-part region was attended on a model's posture as was moved by the participant.

movement. Order was counterbalanced across participants.

## Results and discussion

Proportion error was calculated for each body region cued in each moved body part as in Experiment 1. No participants were at ceiling performance and one participant was excluded from the analysis for exceeding the 35% error-rate criterion.

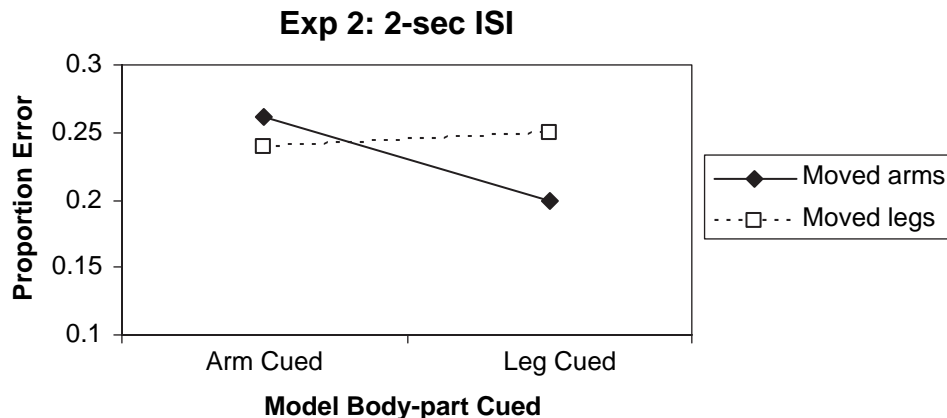
A Body Part Moved (arms, legs)  $\times$  Body Part Cued (arms, legs) ANOVA was conducted. The critical interaction between participant's Body Part Moved (arms, legs) and model's Body Part Cued (arms, legs) was significant,  $F(1, 39) = 4.91$ ,  $p < .05$ . The direction of the interaction indicated that attending and moving the same body-part region reduced memory performance (Figure 4). Post hoc contrasts revealed that when cued to the model's leg region, participants produced more errors when moving their legs than when moving their arms,  $F(1, 39) = 5.04$ ,  $p < .05$ . When cued to the model's arm region, participants produced more errors when moving their arms than when moving their legs,  $F(1, 39) = 8.64$ ,  $p < .01$ . Although arm and leg movement were equally difficult, body part moved,  $F(1, 39) < 1$ , arm postures were more difficult to distinguish than leg positions, body-part cued,  $F(1, 39) = 3.95$ ,  $p = .05$ .

In sum, a 2 s ISI produced an error pattern consistent with the common code model. Performance on the primary memory task was relatively worse when the participant moved the same body

parts as cued on the model. The interaction moves in the opposite direction of the interaction in Experiment 1. Although the visual similarity of the body stimuli between the primary and secondary tasks could have produced the relative interference effect, the relative facilitation effect found in Experiment 1 suggests that this is not the case. To confirm the differences in interactions for the two experiments, we conducted a post hoc analysis to compare the results of Experiments 1 and 2. An ANOVA with the factors Experiment (Experiment 1: 5 s ISI; Experiment 2: 2 s ISI)  $\times$  Body Part Moved (arms, legs)  $\times$  Body Part Cued (arms, legs) produced a significant three-way interaction,  $F(1, 50) = 6.74$ ,  $p < .01$ , and no other effects. These results suggest that at the 2 s ISI, visual and motor inputs compete for the same region of the spatial body representation; however, by 5 s that competition can be resolved and the common portion of the body representation can be co-activated.

## EXPERIMENT 3

Experiments 1 and 2 established that processing time influences the performance consequences of visual-motor integration with long-term, multi-modal, articulated spatial body representations. Experiment 3 addresses the cross-modal aspect of this interaction and whether any secondary body-related task could produce the body-part-specific interaction. Specifically, it examines whether the body-part specific effect is purely visual and could be obtained simply by viewing changing body positions in a secondary task. Further, it provides



**Figure 4.** Experiment 2. With a 2 s ISI, a significant body-part-specific interaction (i.e., the Body Part Moved  $\times$  Body Part Cued interaction) was found that revealed relatively worse performance when the same body-part region was attended on a model's posture as was moved by the participant.

insight into whether explicit movement is *necessary* to induce the body-part-specific effects of the previous experiments.

Neurophysiological single-cell recording research has argued for a common neurocognitive basis for perception and action. The neural response from “mirror neurons” to viewing body positions might be similar to actually producing them (e.g., Graziano, 1999; Rizzolatti, Fadiga, Fogassi, & Gallese, 2002; Rizzolatti et al., 1996). Graziano (1999) used single-cell recording in monkeys to provide evidence supporting the dominating role of vision in body schemata. This neurophysiological research documents that, in primates, the mere viewing of another body performing goal-related actions is sufficient to activate mirror neurons that also represent the primate’s own actions (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995; Rizzolatti et al., 1996; see Rizzolatti et al., 2002, for a review). Further, this idea is supported by human neuropsychological and neuroimaging research (Brugger, Kollias, Muri, Crelier, & Hepp-Raymond, 2000; Stevens, Fonlupt, Shiffrar, & Decety, 2000). The observation of another individual’s movement appears to be sufficient to engage the stationary observer’s premotor system. Thus, a reasonable hypothesis is that visual experience and/or innate processes may be adequate to generate the limb-specific effects without motor activity.

In Experiment 3, the primary body-position memory task was the same as in the previous experiments. However, the secondary movement task was replaced with a body-related *viewing* task. The visual secondary task is similar to the original movement task: participants view a series of poses in which the arm position or the leg position changed from pose to pose. The difference is that in the viewing task, a small number of new poses were added that matched the position of the primary-task model. Participants determine whether any of the poses in the series match the position of the memory pose from the primary task, but participants do not move. This visual secondary task requires the representation of several body postures because participants are required to make judgments about the postures. This visual secondary task was pilot tested to be of roughly equal difficulty to the secondary movement task. If viewing changing body positions were sufficient to activate on-line motor representations, then a significant interaction between body part viewed and model’s body part cued should be found.

## Method

*Participants.* A total of 40 undergraduates from the University of Denver participated for extra course credit in psychology courses. All participants had normal or corrected-to-normal vision. They were assigned randomly to one of two conditions: a 2 s ISI condition ( $n = 20$ ) or a 5 s ISI condition ( $n = 20$ ).

*Stimuli and apparatus.* The stimuli, design, and procedure were similar to Experiments 1 and 2. The primary task was exactly the same. The secondary task was altered to conform to the requirements of the dual-task paradigm, and to ensure that participants were engaged in a secondary, no-movement task in which the body stimuli were attended. The arm and leg stimuli of the secondary task from the previous experiments were used for the new secondary task: either pictures of a model sitting with his arms in a particular position and his legs in a neutral position with knees together in front of him, or pictures of a model sitting with his legs in a particular position and his arms in a neutral position at his sides. In addition, several new arm and leg poses were created for the new secondary task in which the arm positions or the leg positions matched a pose used in the primary task. These new abstract body poses were created with the same size and requirements as the other stimuli. The same software was used to create them (see Experiment 1 method section). However, they are different from the other secondary-task poses because the other secondary-task poses were explicitly created not to match any of the poses used in the primary task. In any series of poses, only one pose could match the primary-task pose. Matching poses occurred infrequently on 10% of the trials.

*Design and procedure.* The primary task procedure was exactly the same as Experiments 1 and 2, with the exception that (same/different) judgments were recorded using a four-button response box instead of a voice key. Using their index fingers, participants pressed the far right key with their right hand if the two stimuli were the same and the far left key with their left hand if the two stimuli were different.

For the secondary non-movement task, participants viewed a series of poses on the left computer monitor while they concurrently

performed the primary memory task. Their job was to determine whether the cued body part of any of the poses in the series matched the same body part in the memory pose. On 10% of the trials, a single match occurred between one of the secondary poses and primary task model pose. The matched pose in the secondary task could occur in any position in the series. Its position was randomly presented in the sequence. No movement was permitted during the trial. Participants responded verbally “Yes” or “No” if a match between the primary and secondary task poses occurred during the trial.

The blocks of arm or leg “movement” (i.e., the model in the secondary task changed position) were counterbalanced across participants. After participants responded to the primary task with a button press, they were asked to verbally report whether there was a position match of the primary-task postures with one of the secondary-task postures. The experimenter recorded the second response. By altering the secondary task in this way, participants were still focused on either the arm or the leg positions, they still watched a series of arm or leg positions on a second monitor while they remembered another body position presented on the primary monitor. However, the most important aspect of this task is that they had to perform a secondary task that required attention to changing arm or leg positions but that explicitly prohibited participant movement. In this way, we tried to preserve the requirements and conditions of the previous experiments as much as possible, with the exception of participant movement.

Experiment 3 used a mixed-factor design. Participants were randomly assigned to one of two groups, the 2 s ISI group or the 5 s ISI group. The within-subject factors were participant’s Body Part Viewed (arm movement, leg movement) and model’s Body Part Cued (arms, legs). The critical analysis was the three-way interaction: ISI  $\times$  body-part viewed  $\times$  body part cued. If viewing were sufficient to activate the motor representations, then three-way interaction should be significant. If the processing time hypothesis holds without overt movement in the secondary task, then the error patterns should be similar to those found for the movement secondary task performance in Experiment 3: the 2 s ISI group should demonstrate body-part-specific error patterns consistent with relative interference and the 5 s ISI group should demonstrate body-part-specific error patterns consistent with rela-

tive facilitation. However, if motor activation were necessary for the body-part-specific, cross-modal interaction, then no interactions should be found.

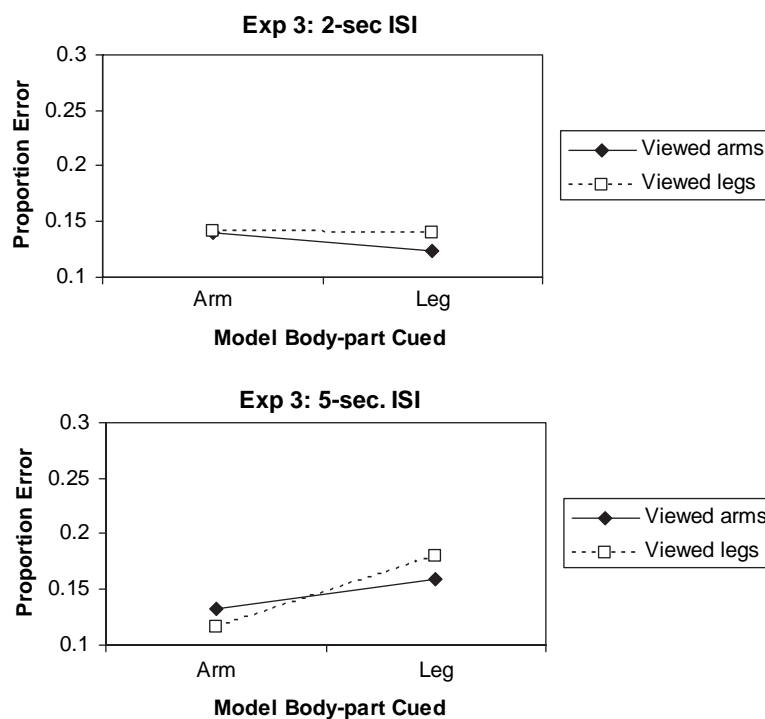
## Results and discussion

Proportion error was calculated for each body region cued on the model in each body part viewed for each ISI condition as in the previous experiments. To determine if visually perceived movement could produce a body-part-specific interaction, a three-way ANOVA was conducted with the between-subject factor of ISI (2 s, 5 s) and the within-subject factors of Body Part Viewed (arms, legs) and Model’s Body Part Cued (arm, leg). Contrary to what might be expected if the mirror neurons were supporting the visual-motor interaction, the three-way interaction did not approach significance, ISI  $\times$  Body-Part Viewed  $\times$  Body-Part Cued:  $F(1, 38) < 1$  (Figure 5). The only significant effect was the Body Part Cued  $\times$  ISI interaction,  $F(1, 38) = 5.67$ ,  $p < .05$ , indicating that memory for cued leg positions was worse than for cued arm positions for the 5 s condition only. There were no other significant main effects or interactions, ISI:  $F(1, 38) < 1$ ; Body Part Viewed:  $F(1, 38) < 1$ ; Body Part Cued:  $F(1, 38) = 3.0$ , *ns*; Body Part Viewed  $\times$  ISI:  $F(1, 38) < 1$ ; Body Part Viewed  $\times$  Body-Part Cued:  $F(1, 38) = 2.21$ , *ns*.

In conclusion, the body-part-specific interaction was not found for a secondary task that required body-related processing at either the 2 s or the 5 s ISI. Viewing body stimuli was not sufficient to produce the body-part-specific interactions found in the previous experiments. Although mirror neurons can provide insight into the building blocks of perception-action correspondences of simple, goal-directed actions and support higher-level processing, they do not appear to be sufficient to drive more complicated tasks such as this one. We do not want to interpret a null result, but these findings suggest that actual movement may be necessary to create visual-motor interactions.

## GENERAL DISCUSSION

Humans are embodied and optimized to process “like me” information. Social perception is facilitated by creating self-other correspondences through the integration of information about



**Figure 5.** Experiment 3. The Body Positions Viewed  $\times$  Body Part Cued interaction was not significant for either of the between-subject 2 s or 5 s ISI dual-task body-viewing conditions.

the observer's own body and others' bodies. This information can be helpful in understanding what the other person is feeling and intends to do as well as informing the observer on how to respond (Niedenthal et al., 2005; Reed & McIntosh, 2007). Specialized body representations and mechanisms permit processing efficiencies to help organize information from other people's bodies (Reed et al., 2006b; Shiffrar, 2006). Fundamental to self-other mapping is the spatial body representation, or the body schema, that contains the basic spatial layout and biomechanics of the human body to help organize perceptual inputs of other bodies (Reed, 2002).

Research has suggested that humans have shared representations for the perception and production of action (e.g., Bertenthal, 1993; Parsons et al., 1995; Prinz, 1997; Thornton, Pinto, & Shiffrar, 1998; Vivianni & Stucchi, 1992). Although distinct visual and motor representations are created during perception and action, they become integrated into a common representation (e.g., Prinz, 1997, 2002). In this study we examined how personal action can influence the visual body perception of other people in terms of creating self-other correspondences and by comparing two models that propose different mechanisms underlying these self-other

correspondences. The facilitation model (e.g., Reed & Farah, 1995) proposes that given the importance of social perception and learning, correspondences between one's own body and others bodies, self-other correspondences should always facilitate performance because both inputs contribute to the increased activation of a common portion of the body representation. In contrast, the common code model (Prinz, 1997) proposes that the creation of self-other correspondences leads to the competition between visual and motor inputs for the same part of the body representation and interfere with performance. A modification of this theory is that the multimodal inputs can co-activate a common portion of the body representation only after this conflict is resolved.

To investigate the consequences of concurrent visual and motor inputs to the body representation, we modified the dual-task paradigm introduced by Reed and Farah (1995) and manipulated the time that the visual and motor inputs could be integrated. Participants performed a visual body-position memory task while they executed movements of their arms or legs. Experiment 1 replicated Reed and Farah's 5 s ISI. Experiment 2 reduced the ISI to 2 s. We predicted that if the facilitation model held, then we should find a

body-part-specific interaction between the moved and viewed body parts and that regardless of processing time, performance would be relatively improved if the moved body part was the same as the attended body part. If the common code model were supported, then we should replicate the relative facilitation effect for the 5 s ISI but not for the 2 s ISI. At the 2 s ISI the conflict between inputs could either result in no interaction or relatively decreased performance if the moved body part was the same as the attended body part. For both models and experiments, a significant body-part-specific interaction would indicate the creation of self-other correspondences and the common access of the spatial body representation.

The results of Experiments 1 and 2 provided support for the integration of visual and motor inputs into a common body representation. The multimodal perceptual system created self-other correspondences in that both experiments produced significant body part moved  $\times$  body part viewed interactions. The replication of body-part-specific interactions for visual and motor inputs confirm that the long-term body representation is articulated (i.e., it distinguishes arms from legs), multimodal, and used for the self and others (Reed, 2002; Reed & Farah, 1995; Slaughter & Heron, 2004).

However, the two experiments differed in the direction of this interaction. For Experiment 1 with the 5 s ISI, error patterns indicated relative facilitation for body-part memory, replicating the results of Reed and Farah (1995). For example, when participants moved their arms while trying to remember the position of another individual's arms, their memory for arm position relatively improved. In contrast, for Experiment 2 with the 2 s ISI, error patterns indicated relatively worse body-part memory: if participants moved their legs, their memory for the model's leg position was impaired relative to their memory for the model's arm position. Thus, the results support the modified common code model and suggest that processing time is needed to resolve the conflict of multimodal inputs to the same representation. Experiment 3 indicated that not all body-related secondary tasks produced a body-part-specific interaction and suggested that overt movement may be critical.

In the present task, visual and motor inputs accessed a common spatial body representation. More specifically, activity in the visual system competed with activity in the motor system during the stimulus presentation and ISI. When

both inputs required the activation of similar body-part regions (i.e., legs or arms), two overlapping activations had to be integrated into the spatial body representation. For the shorter 2 s ISI, the motor input competed with the visual input for integration with specific portions of the long-term body representation. Schuböe et al. (2004) have argued that there may also be a mechanism that emphasizes the differences between the two inputs and keeps them initially distinct. For the longer 5 s ISI, concurrent visual and motor inputs also activated similar portions of the long-term body representation. However, it appears that the two inputs were able to settle the initial competition when correspondences were found between them, thereby allowing them to become integrated with the body representation. The mechanism that initially increases the contrast between the two inputs may weaken with time, allowing increased activation of the portion of the body representation that was common for both vision and proprioceptive input.

Common code theory is agnostic about the processing stage or domain in which common codes exist (e.g., Schuböe et al., 2004). However, sensorimotor working memory may be the processing stage at which perceptual inputs and long-term body representations interact. Wilson (2001) argues that working memory contains sensorimotor representations that help extend the capabilities of on-line processing. Within working memory, both on-line visual and motor representations can be activated concurrently with the long-term spatial body representation. Such integration of perceptual and long-term representations may permit the performance of tasks such as imitation and understanding the actions of others (Meltzoff & Moore, 1995; Wilson, 2001). The efficient maintenance of information in working memory depends on the ability to do rapid cycling between quasi-perceptual and quasi-motoric versions of the same represented information. This process allows the mapping of a visually perceived body onto one's own body representation and the resulting information feeding back downward to affect the ongoing perception and memory (Wilson, 2001).

Further, if the body-part-specific interaction comes from interactions in working memory, then common code theory may also provide some insights into another aspect of our findings: the 5 s ISI did not show a deterioration of memory performance compared to the shorter 2 s ISI. We suggest that any decay in working memory of the

sensory inputs might be mediated by the activation of the long-term body representation. During the 5 s ISI this representation may be activated to support the integrated body posture representations and to counteract their decay from short-term memory.

Although working memory appears to be a good candidate source for the cross-modal integration, one alternative explanation is that the body-part-specific interaction is a function of the allocation of attention resources to different specific portions of the body representation. In our task, we cued participants to a particular body region prior to each trial, but previous work has shown that explicit cuing is not necessary and that movement of one's own body may be enough to draw attention resources to the same portion of another's body (Reed & Farah, 1995). Attention to a portion of the body posture may influence the remaining attention resources to encode the rest of the body posture. One could suggest that attention to a common body region could interfere with performance because the vision and the motor inputs access the same resources or one could suggest that attention to common body regions could draw limited resources to that region and facilitate performance. However, it is difficult to see how either one of these mechanisms could account for the changing direction of the interaction with time.

Last, we turn to the question of why might it be important to have both facilitation and interference processes for social perception. The functional utility of the facilitation process is clear for observational skill learning, imitation, and understanding another's emotional state. Facilitation of performance occurs quickly when the self and other match as in mimicry or direct imitation (McIntosh, 1996, 2006; Moody & McIntosh, 2006), but our study shows that it can happen even when the self and other do not match as long as perceptual inputs activate a common portion of the body representation and that enough processing time is allowed to resolve the initial competition. The body representation may assist in this process by providing a cross-modal template upon which one can come to understand others (Meltzoff & Moore, 1994).

Thus, self–other correspondences can help us form perceptual goals based functionally around what other people are currently doing. Knowing what another person is about to do increases the chances that one's own responses will be appropriate as well as increasing one's ability to under-

stand the other person's actions. However, there is also functional and social utility in keeping inputs from the self and other separate, especially when the behavioral goal is not to match the self and other. For example, when one sees another person in emotional crisis it may be most functional not to match that person's emotional state and to keep one's own emotional state separate.

In conclusion, correspondences between one's own body and another person's body occur whether the behavioral goal is to match the other person or not, and whether additional processing time is given to the observer or not. In this study, both of our experiments produced body-part-specific interactions suggesting that the same body representation was accessed. However, processing time appears to influence the performance consequences of creating self–other correspondences. After initial competitions from multimodal body inputs, we have demonstrated that additional processing time can facilitate self–other correspondences and improve body processing.

These findings have implications for individuals with social-emotional processing deficits such as those found in autism. It is possible that individuals with autism may not spontaneously create self–other correspondences and co-activate the spatial body representation. For example, these individuals tend not to mimic other's faces spontaneously (McIntosh, Reichman-Decker, Winkelman, & Wilbarger, 2006) and do not show body inversion effects (Reed, Beall, Kopeliov, Pulham, & Hepburn, 2006c). This is consistent with research on the neural networks involved in social processing that are atypically activated, and may not integrate multimodal regions that are involved in body processing (Allison, Puce, & McCarthy, 2000; Frith, 2001; Frith & Frith, 2001). However, this may also be a relevant topic for future study to determine if tasks that explicitly indicated the need for self–other correspondences and permitted additional processing time could improve social interactions in these populations.

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