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Viewpoint and the Recognition of People From Their Movements

Sapna Prasad and Maggie Shiffrar
Rutgers, The State University of New Jersey, Newark

Observers can recognize other people from their movements. What is interesting is that observers are best able to recognize their own movements. Enhanced visual sensitivity to self-generated movement may reflect the contribution of motor planning processes to the visual analysis of human action. An alternative view is that enhanced visual sensitivity to self-motion results from extensive experience seeing one's own limbs move. To investigate this alternative explanation, participants viewed point-light actors from first-person egocentric and third-person allocentric viewpoints. Although observers routinely see their own actions from the first-person view, participants were unable to identify egocentric views of their own actions. Conversely, with little real-world experience seeing themselves from third-person views, participants readily identified their own actions from allocentric views. When viewing allocentric displays, participants accurately identified both front and rear views of their own actions. Because people have little experience observing themselves from behind or from third-person views, these findings suggest that visual learning cannot account for enhanced visual sensitivity to self-generated action.

Keywords: biological motion, viewpoint, identity perception, perception–action coupling, perceptual learning

Human observers can identify individual people from movement cues alone. For example, when human action is reduced to a few point lights (Johansson, 1973), individuals can recognize their own gaits and the gaits of their friends from the movements of those point lights (e.g., Cutting & Kozlowski, 1977; Jokisch, Daum, & Troje, 2006). The ability to recognize others and oneself is essential for successful social interaction. What processes allow observers to distinguish their own actions from the actions of other people?

Previous studies of person recognition from motion cues alone have emphasized the role of perception–action coupling. Part of the motivation behind this theoretical focus is the finding that observers demonstrate greater visual sensitivity to their own actions than to the actions of other people. For example, Beardsworth and Buckner (1981) reported that participants more accurately identified point-light depictions of their own gaits than the gaits of their friends. More recent research indicates that enhanced sensitivity to self-generated actions generalizes across a wide variety of actions and does not depend on static cues to body shape (Knoblich & Prinz, 2001; Loula, Prasad, Harber, & Shiffrar, 2005). Furthermore, observers can predict the perceptual consequences of their own actions more accurately than the consequences of other people's actions (Knoblich & Flach, 2001). Because observers have the greatest motor experience with their own actions, enhanced visual sensitivity to self-generated actions suggests that motor processes influence the visual analysis of human action (e.g., Prinz, 1997; Shiffrar & Pinto, 2002; Viviani & Stucchi, 1992; Wilson, 2001).

Evidence from brain imaging studies further supports motor-based theories of action perception. For example, the neural mechanisms involved in the differentiation of self- and other-generated actions are deeply entrenched within the action production system (Blakemore, 2003; Daprati & Sirigu, 2002). Indeed, a stationary individual's own motion system is activated during the passive observation of actions that he or she can perform (e.g., Calvo-Merino, Glaser, Grezes, Passingham, & Haggard, 2005; Hari et al., 1998) but not during the observation of actions that he or she cannot perform (Stevens, Fonlupt, Shiffrar, & Decety, 2000). Temporal differences in the onset of motor system activation may help observers differentiate their own actions from the actions of others (Grezes, Frith, & Passingham, 2004).

Although the above findings paint a compelling picture of the importance of motor experience in the visual analysis of human action, a potentially important factor muddles this interpretation. Simply put, motor experience is inherently confounded with visual experience. Every time you eat, walk down stairs, or light a cigarette, your retinas record images of your own actions. This raises the question of whether enhanced perceptual sensitivity to one's own actions results, fully or in part, from the massive observational experience that people have with their own actions.

Perceptual learning defines many perceptual and cognitive processes by modifying and sharpening relevant discrimination abilities (Gibson, 1969). For example, individuals have a lifetime of experience watching other people move, and this visual experience can enhance visual sensitivity to the human movement (Bulthoff, Bulthoff, & Sinha, 1998; Giese & Poggio, 2003; Johansson, 1973). Previous tests of this hypothesis have shown that the ability to differentiate between two different point-light actors depends on whether those actors walk with commonly seen gaits or rare gaits

Sapna Prasad and Maggie Shiffrar, Department of Psychology, Rutgers, The State University of New Jersey, Newark.

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Correspondence concerning this article should be addressed to Maggie Shiffrar, Department of Psychology, Rutgers University, Newark, NJ 07102. E-mail: mag@psychology.rutgers.edu

(Jacobs, Pinto, & Shiffrar, 2004). Furthermore, visual sensitivity to gait speed is superior for frequently observed gaits than for rarely seen gaits (Jacobs & Shiffrar, 2005). Thus, behavioral evidence suggests that visual sensitivity to human action depends on the amount of previous experience that observers have had watching particular actions. Consistent with this, neural activity in the posterior region of the superior temporal sulcus, a visual area known to process biological motion (e.g., Bonda, Frey, & Petrides, 1996; Oram & Perrett, 1994), is modulated by visual experience (Grossman & Blake, 2001). Furthermore, computational models indicate that some aspects of biological motion perception can be explained by visual experience alone (e.g., Giese & Poggio, 2003). Additionally, the fact that observers can accurately identify their friends in point-light displays clearly supports the idea that visual learning influences biological motion processes (Beardsworth & Buckner, 1981; Cutting & Kozlowski, 1977; Jokisch et al., 2006; Loula et al., 2005). Altogether, substantial evidence suggests that visual sensitivity to human action is influenced by perceptual experience. Indeed, Gunnar Johansson, the originator of the point-light technique in vision research, attributed the compelling nature of point-light actions to visual experience (Johansson, 1973).

Although the frequencies with which one produces and perceives one's own actions are confounded, manipulations of viewpoint offer a means of decoupling them. Observers have a lifetime of experience visually perceiving their own actions from an egocentric or first-person viewpoint. However, aside from watching oneself in movies or mirrors, observers have little experience perceiving their own actions from an allocentric or third-person viewpoint. Obviously, the reverse pattern holds for the perception of other people's actions because observers view others, by definition, from a third-person perspective (see Figure 1). To the extent that visual sensitivity to self-generated actions is defined by viewpoint-dependent visual experience, observers should demonstrate greater perceptual sensitivity to egocentric views of their own actions than to allocentric views. Thus, in an actor identification task, observers should be better able to identify their own actions from egocentric views than from allocentric views. Note that motor experience with an action is independent of one's viewpoint on that action. Thus, in the experiments below, we manipulated viewpoint to decouple the contributions of visual learning and motor processes to action perception.

In a previous study on the role of viewpoint in the identification of point-light actors, Jokisch and colleagues (2006) displayed walking point-light people from three different allocentric views: frontal, half profile, and profile. The identification of friends' gaits varied with viewpoint, whereas identification of each observer's own gait did not. Because that research was restricted to allocentric views, it remains to be determined whether the ability to identify one's own actions is fully viewpoint independent.

Experiment 1: Discrimination of Point-Light Actors Across Egocentric and Allocentric Views

People have a lifetime of egocentric experience perceiving their own actions. To the extent that viewpoint-dependent perceptual learning defines perceptual sensitivity to self-generated actions, observers should demonstrate the greatest perceptual sensitivity to egocentric views of their own actions. By the same logic, observers should also demonstrate the greatest perceptual sensitivity to allocentric views of the actions of other people.

Previous studies provide apparently conflicting insights on these predictions. Developmental research has demonstrated that 5- and 7-month-old infants are better able to recognize their own leg movements from egocentric point-light displays than from allo-

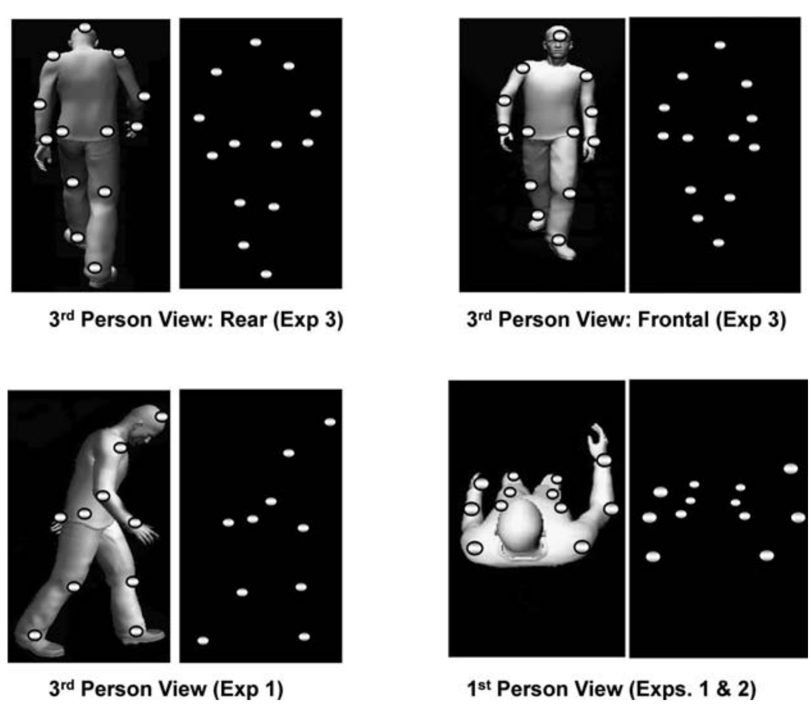

Figure 1. A diagram of the third-person and first-person viewpoints used in Experiments (Exps.) 1–3.

centric displays (Schmuckler & Fairhall, 2001). In these studies, infants simultaneously moved their legs while observing egocentric point-light displays of those leg movements. Under these conditions, infants could differentiate point-light displays of their own leg movements from the leg movements of other infants. This result suggests that adult observers might be particularly sensitive to egocentric displays of their own bodily actions. On the other hand, psychophysical studies with adults suggest that observers have difficulty perceptually organizing point-light displays of human gait from an axial perspective (Bulthoff, Bulthoff, & Sinha, 1997). Bulthoff and her colleagues (1997) suggested that this perceptual difficulty results from the unusualness of such an egocentric viewpoint, whereas Schmuckler and Fairhall (2001) argue that this egocentric viewpoint is the usual perspective that people have on their own bodies.

To determine whether enhanced perceptual sensitivity to one's own actions can be attributed to visual experience, naive observers in Experiment 1 performed an identity discrimination task with point-light displays of themselves, their friends, and matched strangers depicted from egocentric and allocentric perspectives.

Method

Participants. Nine participants were recruited for this study from the Newark campus of Rutgers, the State University of New Jersey, for financial compensation. All participants were naive to the hypothesis under investigation. Unbeknownst to these participants, they were preselected in triplets. Each participant was experimentally paired with 1 friend and 1 stranger. Of the 9 participants, 3 were involved only in the generation of the stranger stimuli (and are henceforth referred to as *strangers*) and did not participate in the subsequent testing session. The remaining 6 participants played a dual role in this research. By acting in the initial point-light movies, they served in stimulus generation. Later, these 6 participants also served as observers who attempted to identify themselves, their friends, and their assigned strangers.

The 6 actor–observer participants were three pairs of friends. Friends were defined as people of the same gender who spent at least 10 hr a week together over the past year. Friendship pairs were also restricted to people of similar ages and physical proportions to ensure that observers could not use gender (Pollick, Kay, Heim, & Stringer, 2005) and/or weight (Runeson & Frykholm, 1983) as the basis for their discriminations. None of the participants had a medical condition that prohibited them from engaging in requested motor activities. All participants had normal or corrected-to-normal vision and provided informed consent before beginning the experiment.

Apparatus. All action sequences were filmed with a Viosport Adventure II Head Camera (Viosport, Marquette, MI) and a Canon ZR60 digital camcorder. After editing, the stimuli were displayed on a Macintosh 21 in. (34 cm $\times$ 26 cm) monitor set at an 800 $\times$ 640 pixel resolution. A Power Macintosh G4 was used to control stimulus presentation and data collection. Observer responses were collected with a Macintosh keyboard. A chin rest was used to fix observers' viewing distance at 54 cm from the monitor.

Stimulus generation. All 9 participants were individually filmed as point-light actors. These point-light displays were created by modifying Johansson's (1973, 1975) classic technique. Participants were simultaneously filmed from both an egocentric and an allocentric viewpoint. To create movies from the egocentric perspective, the Viosport Adventure II Head Camera was mounted at the actor's eye level to the front of a specially constructed helmet that participants wore on their heads. Simultaneously, these participants were filmed with the Canon ZR60 digital camcorder from an allocentric view. Each participant was dressed in fitted black clothes to which reflective white markers were attached to their major joints and head. Thirteen markers were visible to the allocentric view camera (see Figure 1) and 12 (13 minus the head marker) were visible to the eye-level egocentric camera.

Each participant performed a series of 10 actions while being filmed with both cameras. Participants performed each action for 3 min. The 10 actions included the following:

1. Jumping in place
2. Walking at 2.4 mph on a flat treadmill
3. Greeting by waving hello and shaking hands with another person
4. Whole body laughing
5. Playing Ping-Pong against a wall
6. Hugging another person
7. Walking at 2.4 mph up a treadmill with a 7.5% incline
8. Hitting a punching bag
9. Running at 3.4 mph on a flat treadmill
10. Dancing to a particular pop song

Real props (i.e., punching bag, Ping-Pong paddle) and real interactions were used during filming so that the movement dynamics were realistic. Before filming, the experimenter modeled each action for each participant. Actors were instructed to move naturally. Before filming, all participants were told that their actions would be used in a study of action, rather than actor, identification. Thus, naturalistic actions were emphasized.

Once filming was completed, the resultant digital movies were imported to a Macintosh computer and edited with i-Movie and QuickTime software. To create the point-light displays, each video segment was edited so that only the white markers were visible against a homogeneous black background. Each 3-min movie was cut into 13 clear and distinct 5-s depictions of each action. Thus, for each participant, a library of movies was created for each of the 10 different actions from egocentric and allocentric viewpoints.

Procedure. Participants completed two testing sessions separated by a 1-month interval. For half of the participants, the first testing session depicted point-light displays from the egocentric viewpoint and the subsequent session depicted point-light displays from the allocentric viewpoint. For the other participants, the reverse order was used. The delay between sessions was intended to minimize transfer across viewpoints. In each testing session, participants were told that they would view point-light displays of themselves, their assigned friend, and an assigned stranger. Participants viewed 120 trials (10 actions $\times$ 12 performances) from each actor for a total of 360 trials per viewpoint condition. On each trial, two different actions were depicted sequentially. On half of the trials (180 trials), the same actor performed the two actions. Thus, each participant saw 60 "same" trials for each of the three actors. On the remaining trials, two different actors performed the two actions. Thus, each participant viewed 60 self–friend combinations, 60 friend–stranger combinations, and 60 stranger–self combination trials for a total of 180 "different" trials. At the end of each trial, participants pressed one key if they thought that the two actions were performed by the same actor and another key if the two actions were performed by different actors.

In each testing session, trial order was randomized across actions, actors, and participants. Each observer completed one block of 15 practice trials before beginning the experimental trials. Different movies were used in the practice and experimental trials. During the practice trials, the experimenter identified the joint location for each point light to establish a baseline in participants' understanding of the spatial layout of the point-light display. No feedback was provided during or after the practice or experimental trials. One complete testing session (practice plus experiment trials) lasted about 60 min.

Results

Identity discrimination accuracy for each participant was calculated for each actor for each viewpoint. Errors could not be clearly categorized in the different actor trials because the identity of either actor could have been misperceived. Therefore, discrimination accuracy was calculated only for the trials in which the same actor performed both actions. A 2 (viewpoint) × 3 (actor) repeated measures analysis of variance (ANOVA) revealed an overall main effect for viewpoint (egocentric or allocentric), $F(1, 5) = 14.87$, $p < .001$; no significant main effect for actor (self, friend, or stranger), $F(2, 5) = 1.40$, $p > .25$; and a significant interaction between viewpoint and actor, $F(1, 2) = 3.38$, $p < .05$.

Significant main effects and interactions were further analyzed by post hoc examination with Bonferroni corrections made for multiple comparisons when appropriate. When the data are broken down by viewpoint, the cause of the lack of a main effect of actor is clear. A post hoc *t* test indicated that performance with the egocentric displays, shown in Figure 2A, did not significantly differ from chance, or 50%, in this two-alternative forced-choice (2AFC) task, $t(5) = 2.51$, $p = .124$. A repeated measures ANOVA on the egocentric view data revealed a nonsignificant main effect of actor (self, friend, or stranger), $F(2, 5) = 1.15$, $p = .33$. Conversely, for the allocentric view data (see Figure 2B), a repeated measures ANOVA revealed a significant main effect for actor, $F(2, 5) = 3.52$, $p < .05$. Paired post hoc *t* tests, with the significance level for each set to $p = .0167$ (Bonferroni corrected $p = .05$ divided by 3 [number of clustered *t* tests]), revealed significant performance accuracy differences between self and friend trials, $t(5) = 3.62$, $p = .015$; between self and stranger trials, $t(5) = 6.34$, $p = .001$; and between friend and stranger trials, $t(5) = 2.69$, $p = .014$, in the allocentric view condition. All participants produced this same pattern of data. Furthermore, this pattern of results replicates previous results (e.g., Loula et al., 2005). Computation of the effect sizes for each of these statistically significant differences yielded partial eta-squared values ranging from 0.67 to 0.72 and power from .96 to .99. These values indicate that the results reported here constitute medium to large effects (Cohen, 1988). Most important for the hypothesis under examination, participants were significantly more accurate in the identification of their own actions from allocentric (76% correct) views than from egocentric (44% correct) views, $t(5) = 3.71$, $p < .02$. This result

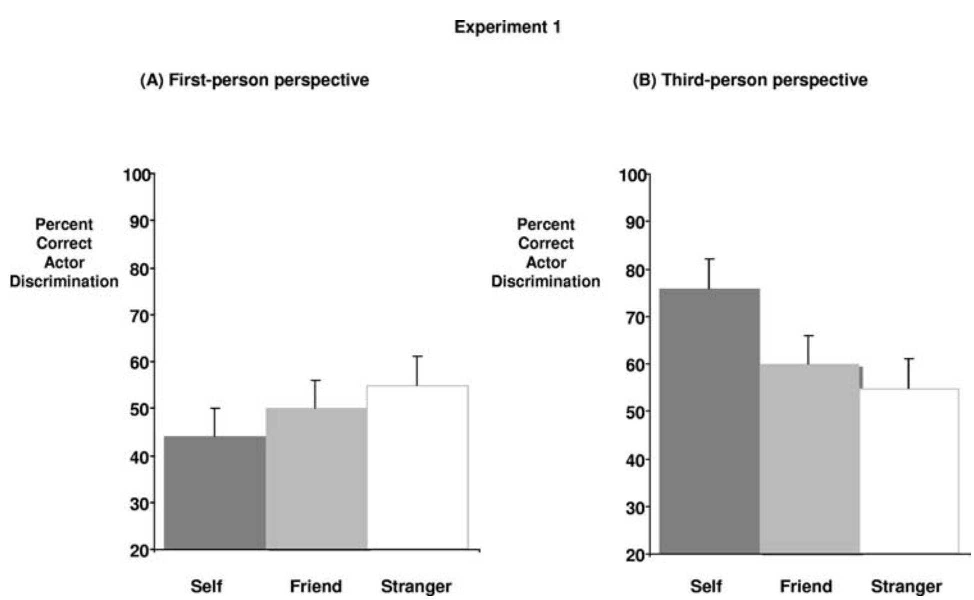

Figure 2. Experiment 1: Performance accuracy from a two-alternative forced-choice actor discrimination task. Point-light stimuli were depicted from (A) the first-person or egocentric view and from (B) the third-person or allocentric view. Results from the same-actor trials are shown. Chance performance equals 50% correct actor discrimination. Error bars indicate standard errors.

is inconsistent with the proposal that visual experience accounts for enhanced visual sensitivity to self-generated actions.

Discussion

Although observers have the most visual experience with egocentric views of their own actions, participants in this experiment were unable to recognize their own actions from the egocentric view. Conversely, participants could accurately recognize actions that they had previously performed when seen from allocentric views. Participants could also recognize the actions of their friend and assigned stranger from allocentric but not egocentric views. From a perceptual learning perspective, this latter finding is not surprising because observers have no experience viewing the actions of another person from the egocentric perspective, that is, from another person's own eyes. Yet, opportunities for perceptual learning from the egocentric viewpoint do not appear to facilitate the recognition of self-generated actions.

The finding that observers demonstrate greater perceptual sensitivity to allocentric depictions of their own actions than to allocentric depictions of the actions of other people is consistent with the hypothesis that the visual analysis of self-generated actions depends on a perception–action matching system (e.g., Prinz, 1997). For example, the direct matching hypothesis (Rizzolatti, Fogassi, & Gallese, 2001) postulates that observers analyze perceived actions by mapping their visual representations of those actions onto motor representations in action planning centers. The tighter the mapping, the more precise the motor constraints on visual analyses of observed actions. Because observation of self-produced actions would produce the tightest possible mapping with motor representations, visual sensitivity would be greatest to those actions. By this logic, observation of other people's actions produces visual representations that do not overlap as tightly with the observer's own motor representations. Decreased representation overlap would lead to decreased visual sensitivity. As a result, observers should demonstrate greater visual sensitivity to their own actions than to the actions of other people.

The theory of intentional schemas (Barresi & Moore, 1996) provides another way to conceptualize such perception–action interactions. According to this theory, a current-imagined schema is thought to link currently perceived information, from a third-person perspective, with imagined information about one's own actions from the first-person perspective. This schema enables action understanding by having an individual imagine producing an observed action. In this case, observation of a self-generated action is more informative because the observed action pattern can be produced by the same system that also imagines the action (e.g., Knoblich & Prinz, 2001). Within this framework, the current results can be further understood as suggesting that because the current-imagined schema is constructed for the perception of third-person views, this system has difficulty linking information perceived from the first-person perspective.

Perceptual limitations in the recognition of self-generated actions viewed from the egocentric perspective are also consistent with previously documented misattribution errors. People can be fooled by indirect visual feedback about ownership of their own actions. For example, "helping hands" studies (e.g., Wegner, Sparrow, & Winerman, 2004) clearly demonstrate that observers can develop the sense that they have authored actions, seen from egocentric views, which are actually performed by another. Additionally, the rubber hand illusion demonstrates that observers can mistake an alien hand for their own hand as long as the alien hand is oriented with the observer's own body (Botvinick & Cohen, 1998). Furthermore, in cases in which the visual perception of arm movement is manipulated through mirrors or videotape (e.g., Jeannerod, 1994), subjects can be led to believe that they are moving their arm to the left, when in fact the basis for this belief is a videotape of someone else moving their arm to the left. The magnitude of this misperception increases when the other person's hand is oriented in the same way as the observer's own hand (fingers pointing away from the body) and when the other person's hand performs the same action as the observer's own hand (Van den Bos & Jeannerod, 2002). These behavioral findings are consistent with neurophysiological evidence of similar patterns of neural activity when observed hands, one's own and others', have similar orientations (Farrer et al., 2003).

Previous results indicated that the ability to recognize one's own actions is invariant across changes in allocentric viewpoint (Jokisch et al., 2006). The current results suggest that this invariance does not generalize to egocentric viewpoints. Superior performance with allocentric views relative to egocentric views of point-light walkers has been previously reported (Bulthoff et al., 1997). Bulthoff and her colleagues (1997) suggested that canonical visual representations of the human body are built on observers' visual experience with allocentric views of other people. According to this proposal, the egocentric displays used here may have been inconsistent with participants' visual–motor representation of themselves and others. Although Bulthoff and colleagues did not investigate perception of identity, their conclusion differs significantly from the assumption of Schmuckler and Fairhall (2001) that infants have and use egocentric representations of their own bodies. It may be that different representations are used during online action perception, as tested by Schmuckler and Fairhall (2001), and offline action perception, as tested by Bulthoff et al. (1997). For example, infants in the Schmuckler and Fairhall (2001) study may have relied, in part, on the temporal contingencies between their actions and percepts. Consistent with this idea, timing has been shown to play a critical role in adult identity perception (Repp & Knoblich, 2004).

The current results suggest that enhanced visual sensitivity to self-generated actions cannot be attributed to visual experience. This conclusion is consistent with perception–action coupling theories in which sensitivity to self-generated actions reflects the contributions of motor processes to action perception. However, the current results are also consistent with an alternative interpretation. Because observers have difficulty perceptually organizing offline, egocentric displays of point-light walkers (Bulthoff et al., 1997), participants in the current study may have been unable to perceptually organize the egocentric point-light displays and consequently unable to perform the identity discrimination task. This explanation is not entirely satisfying because the joints corresponding to each of the point lights were described to participants during the practice trials. Furthermore, previous studies have shown that the motion of a single point is sufficient for observers to identify their own actions (Knoblich & Prinz, 2001). Because the point-light displays used in the current study contained a dozen or more points, observers should have been able to determine the authors of the point-light actions from the motions of the individual points. Yet, chance performance with the egocentric views clearly indicates that participants were not able to determine authorship. Perhaps the presence of multiple point lights was more distracting than informative. Indeed, actor identification is not possible when point-light displays are inverted (Loula et al., 2005). Because inverted displays are difficult to perceptually organize (e.g., Shiffrar, Lichtey, & Heptulla-Chatterjee, 1997; Sumi, 1984), the possibility exists that identity perception is compromised whenever point-light displays cannot be perceptually organized. This potential explanation of the results from Experiment 1 was tested in the following experiment.

Experiment 2: Action Discrimination and Categorization From Egocentric Views

Although people have a lifetime of perceptual experience observing their own actions from their own egocentric perspective, the results from Experiment 1 indicate that observers cannot accurately identify their own actions from this perspective. Previous research indicates that point-light walkers can be difficult to organize when viewed from an egocentric perspective (Bulthoff et al., 1997), although that may not always be the case (Schmuckler & Fairhall, 2001).

Experiment 2 examines whether the inability to recognize egocentric displays of one's own actions is specific to the visual analysis of identity. In this study, naive participants viewed the stimuli from Experiment 1 but discriminated actions instead of actors. Observers can readily identify the actions performed by point-light actors viewed from an allocentric perspective (Dittrich, 1993; Johansson, 1973). If participants cannot identify the actions performed by point-light actors when those actions are depicted from the egocentric perspective, then we can conclude that the participants in Experiment 1 simply could not organize the displays. On the other hand, if participants in this experiment can differentiate egocentrically viewed actions whereas participants in the previous study could not differentiate egocentrically viewed actors, then we can conclude that observers are capable of organizing point-light displays from the egocentric perspective. This latter result would suggest several conclusions. For example, it is possible that observers analyze egocentric views of their own actions for purposes other than self-identification. Another possibility is that recognition of one's own actions from the egocentric viewpoint requires a match between what is seen and what is felt (e.g., Schmuckler & Fairhall, 2001; Van den Bos & Jeannerod, 2002).

Method

Participants. Sixty new participants were recruited for this study from the Newark campus of Rutgers, The State University of New Jersey, for partial credit toward a course requirement. All of the participants had normal or corrected-to-normal vision, and all participants were naive to the hypothesis under investigation.

Stimuli and procedure. The egocentric and the allocentric stimuli from Experiment 1 were used again here. These displays were used in two different tasks: an action discrimination task and an action categorization task. The action discrimination task was used to replicate the type of perceptual judgments made in Experiment 1. Because participants might be able to use local strategies in this action discrimination task (e.g., if points at the top of both movies move in the same way, they must depict the same action), an action categorization task that requires global motion analyses was also included.

In the action discrimination task, each trial consisted of two sequentially presented movies depicting two different actors. In half of the trials, the two actors performed two different actions. In the remaining half of the trials, each of the two actors performed the same action. These actions included all of the actions presented in Experiment 1. The two different walking actions—namely, walking up an incline and walking on a flat surface—were collapsed into one walking category. In each trial, participants viewed each pair of 5-s movies and reported, with a key press, whether the same action or two different actions were depicted.

In the action categorization task, each trial consisted of a single movie depicting an action performed by an actor. As before, these actions included all of the actions presented in Experiment 1. Again, the two walking actions—walking up an incline and walking on a flat surface—were grouped together. At the end of each 5-s movie, a screen appeared with a list of words describing nine possible actions: (a) dancing, (b) boxing, (c) greeting, (d) laughing, (e) Ping-Pong, (f) hugging, (g) jumping, (h) walking, and (i) running. Participants pressed a key to report which one of the nine actions had just been performed.

Twenty participants performed the action discrimination task with egocentric displays, 20 participants performed the action categorization task with egocentric displays, and 20 participants performed the action categorization task with allocentric displays. In all three conditions, the trials were constructed from nine different versions of nine different actions for a total of 81 point-light movies. Nine of these movies were used in the practice trials, and 72 of the movies were used in the experimental trials. In the action categorization task, for both the egocentric and allocentric displays, participants saw each movie twice, in random order, for a total of 144 experimental trials. In the action discrimination task, each of the 72 experimental movies was also shown twice across 72 trials. Before participants initiated the experimental trials, they completed a block of practice trials. During practice, participants were told that each movie depicted a person performing one of the nine actions. As in Experiment 1, the experimenter identified the joint location for each point light to ensure that participants understood the spatial layout of the displays.

Results

In the action discrimination task, the accuracy with which each participant reported whether the two point-light movies in each trial depicted two different actions or two examples of the same action was calculated. Chance performance is 50% correct discrimination in this 2AFC task. A one-sample t test indicated that overall performance (62% correct) was significantly greater than chance, $t(19) = 8.78$, $p < .01$.

In the action categorization task, the accuracy with which each participant chose the correct descriptions of the point-light actions was calculated. Chance performance is 11% correct categorization in this 9AFC task. As shown in Figures 3A and 3B, overall performance in both the egocentric (63% correct) and allocentric conditions (82% correct) was well above chance, $t(19) = 9.23$, $p <$ .01, and $t(19) = 16.63$, $p < .01$, respectively. Participants catego-

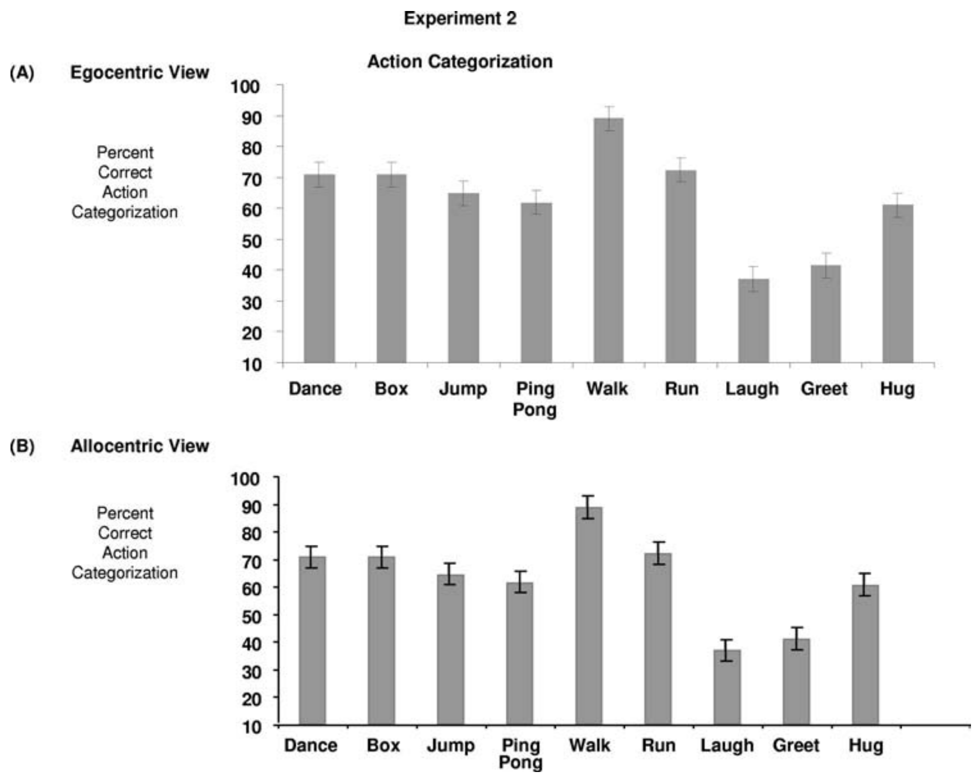

Figure 3. Experiment 2: Performance accuracy from a nine-alternative forced-choice action categorization task with point-light stimuli depicted from (A) egocentric and (B) allocentric views. Performance is broken down by action. Chance performance equals 11% correct actor discrimination. Error bars indicate standard errors.

rized actions more accurately with allocentric views than with egocentric views, $t(38) = 5.35$, $p < .001$.

Discussion

The results of this study indicate that participants can categorize and discriminate point-light actions viewed from the egocentric perspective. We therefore conclude that observers can perceptually organize egocentric views of point-light actions. This conclusion suggests that participants' inability to identify actors from egocentric views (Experiment 1) cannot be attributed to an inability to perceptually organize point-light displays viewed from the egocentric perspective.

Although consistently above chance, performance in the action discrimination and action categorization tasks used here never reached ceiling levels. Performance levels in a previous study of action identification from allocentric views of point-light displays (Dittrich, 1993) are quite similar to performance levels in the current action categorization task with allocentric views. Although participants in the current study were less accurate in their categorization of point-light actions viewed from egocentric perspectives, relative to allocentric perspectives, their performance with egocentric views was nonetheless well above chance, as shown in Figure 3. Thus, the current results appear to conflict with a previous suggestion that observers cannot perceptually organize egocentric views of point-light walkers (Bulthoff et al., 1997). Several factors might account for this difference. First, the egocentric views used by Bulthoff and colleagues (1997) were depicted from a perspective well above the point-light walker's head. Conversely, the views used here were eye based and hence came from each actor's head rather than above it. Eye-based views may be easier to organize than views well above actors' heads. Second, two-dimensional point-light displays were used in the current studies, whereas Bulthoff and colleagues used three-dimensional point-light actors. It is possible that something about the three-dimensional displays used in the Bulthoff studies made them more difficult to organize. Finally, the precision of perceptual organization required for action categorization, depth discrimination, and actor discrimination may simply differ.

In any case, the goal of this experiment was to determine whether observers could perceptually organize the egocentric stimuli from Experiment 1. Performance in the action categorization and discrimination tasks indicates that observers could organize egocentric views of point-light actors at a level sufficient for the identification of actions. Yet, participants in Experiment 1 were unable to identify the actors in these same egocentric stimuli. Thus, although observers are able to perceptually organize egocentric views of point-light actions, they cannot identify the authors of those actions. This result supports the conclusion drawn in Experiment 1; that is, although observers have a lifetime of experience watching their own movements from the perspective of their own eyes, they are nonetheless quite poor at identifying whether they produced actions seen from that egocentric view. This suggests that perceptual learning cannot account for enhanced visual sensitivity to one's own actions.

Observers experience some allocentric views of their own bodies more often than others. Specifically, observers see allocentric, mirror-reversed views of the front of their own bodies when they look in mirrors. Conversely, observers almost never see allocentric views of the back side of their own bodies. If observers can identify their own actions when depicted from behind, then it is difficult to imagine how visual experience could account for enhanced visual sensitivity to self-generated actions.

Experiment 3: Actor Discrimination From the Front and Behind

Although observers frequently use mirrors to watch frontal views of their actions, they very rarely view their own actions from the back sides of their own bodies. Conversely, observers commonly see the fronts and backs of other people in action (see Figure 1). In this final experiment, participants viewed point-light actors depicted from these seen (front self, front others, back others) and unseen (back self) allocentric viewpoints and tried to identify the actors. If observers can identify their own actions from posterior views, then visual experience must be insufficient to account for visual sensitivity to self-generated actions. Alternatively, if observers identify their own actions more accurately from frontal views than from posterior views, then visual sensitivity to self-generated actions must depend, at least in part, on visual experience.

Method

Participants. Twelve new participants were recruited for this study from the Newark campus of Rutgers, The State University of New Jersey, for financial compensation. All participants were naive to the hypothesis under investigation. In a between-subjects design, participants were assigned to one of two allocentric viewpoint conditions (front or back). As in Experiment 1, participants were experimentally paired with one stranger and one friend. During stimulus construction, participants were filmed from both viewpoints so that participants from one condition could serve as strangers for the other condition.

Stimulus generation and procedure. The apparatus and editing process from Experiment 1 were used here. Before filming, 13 point lights were placed on each of the front and back sides of the participants (see Figure 1). Cameras were placed so that they recorded only the markers on the front or back of the participant's body. A subset of the actions used in Experiment 1 (dancing, jumping, Ping-Pong, and jogging) was used here. Approximately 1 month after filming, all participants performed the same 2AFC identity discrimination task used in Experiment 1. Prior to testing, participants were told whether they would see front or back views of the point-light actors.

In the testing session, each participant completed 104 trials (4 actions $\times$ 26 performances per action) for each actor condition (self, friend, and stranger) for a total of 312 trials. Trial order was randomized across actions, actors, and participants. Each participant completed one block of 15 practice trials before beginning the experimental trials. Different movies were used in the practice and experimental trials. No feedback was provided at any time. All other methods replicated those from Experiment 1. As before, on each trial, participants viewed two sequentially presented point-light movies, each of which depicted a different action. Participants then reported whether the same person, or two different people, performed those two actions.

Results

Identity discrimination accuracy for each participant was calculated for the same-actor trials for each actor and viewpoint. Partial eta-squared values were computed for each of the statistically significant effects and showed effect sizes ranging from 0.54 to 0.79 and observed power ranging from .93 to .99, demonstrating that our sample size was sufficient to obtain large effect sizes and ample power (Cohen, 1988).

A 2 (viewpoint) $\times$ 3 (actor) repeated measures ANOVA revealed a borderline, nonsignificant main effect of viewpoint, $F(1, 5) = 3.89$, $p < .06$; a significant main effect of actor, $F(2, 5) = 4.96$, $p < .02$; and no significant interaction between viewpoint and actor, $F(1, 2) = .26$, $p > .77$. This nonsignificant interaction indicates that viewpoint did not affect overall actor discrimination (see Figure 4). Bonferroni-corrected post hoc comparisons on the effect of actor, collapsed across viewpoint, revealed that observers performed the identity discrimination tasks more accurately with the self trials than with the friend trials, $t(11) = 3.16$, $p = .009$, or the stranger trials, $t(11) = 5.93$, $p = .001$. All participants produced this same pattern of data. This result replicates the findings from Experiment 1 and previous studies (e.g., Loula et al., 2005) in demonstrating that observers are significantly better at identifying their own actions than the actions of others.

Discussion

The results from Experiment 3 suggest that observers can accurately recognize their own actions viewed from the front and behind. Thus, although people almost never see their own actions from a viewpoint located behind their own body, observers can identify their own actions from this viewpoint. Indeed, participants demonstrated greater sensitivity to the back views of their own actions than to the back views of the actions of others. This pattern of results is the opposite of what one would predict from visual learning based theories. To the extent that visual sensitivity to the authorship of previously generated human action is defined by visual learning, identity discrimination performance with views that are never seen should be poorer than performance with views that are commonly seen. Although individuals commonly see the actions of their friends from behind, they almost never view their own actions from behind. Nonetheless, participants in this experiment demonstrated greater sensitivity to the back views of their own actions than to the back views of their friends' actions. This result conflicts with visual learning based explanations of visual sensitivity to self-generated actions and is consistent with the hypothesis that the visual analysis of self-generated actions depends instead on a perception–action matching system (e.g., Prinz, 1997; Rizzolatti et al., 2001). According to such perception–action based theories, visual sensitivity to self-generated actions is superior to visual sensitivity to other-generated actions because action observation triggers activation of the observers own motor system

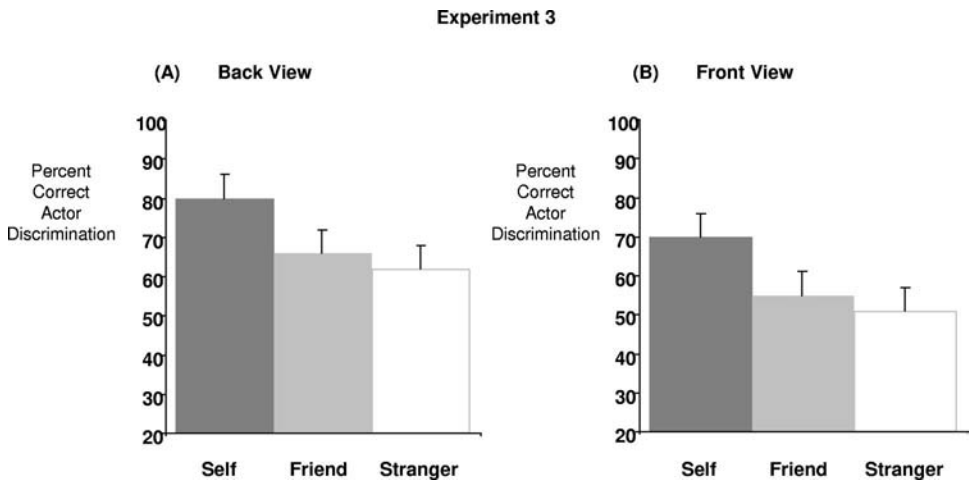

Figure 4. Experiment 3: Performance accuracy from a two-alternative forced-choice actor discrimination task. Allocentric point-light stimuli are depicted from the (A) back and (B) front. Results from the same-actor trial are shown. Chance performance equals 50% correct actor discrimination. Error bars indicate standard errors. In both conditions, identity perception was most accurate when observers viewed their own actions.

(e.g., Loula et al., 2005). One's motor system necessarily carries the most information about one's own actions.

As an aside, two final aspects of the current data merit comment. First, people using mirrors normally see a mirror-reversed, allocentric view of themselves. The fact that observers in this experiment accurately identified their own actions from non-mirror-reversed, allocentric views provides further support for the idea that visual experience with particular views does not define visual sensitivity to self-motion. Second, task performance with back views tended to be slightly, but not significantly, better than task performance with front views of the same actions. When an observer views another person from behind, a spatial alignment is created between the observer's and the observed person's limbs (e.g., the right arm of one person is on the same side of the body as the other people's right arm). This spatial alignment was present in the back view condition. Perhaps such alignment facilitates matching between visual representations of observed actions and motor representations of producible actions.

General Discussion

Numerous studies have documented the human visual system's remarkable sensitivity to human action (for a review, see Blake & Shiffrar, 2007). Here we investigated observers' abilities to identify their own actions and the actions of other people. Previous studies have shown that motion cues are sufficient for the differentiation of self-generated and other-generated motions (e.g., Cutting & Kozlowski, 1977; Jokisch et al., 2006). Furthermore, observers are better able to identify their own actions than the actions of other people (Beardsworth & Buckner, 1981; Knoblich, 2002; Knoblich & Flach, 2001; Knoblich & Prinz, 2001; Loula et al., 2005). The main goal of the current set of psychophysical experiments was to identify the extent to which enhanced sensitivity to one's own actions reflects a lifetime of visual experience with self-generated actions (e.g., Bulthoff et al., 1998; Giese & Poggio, 2003; Johansson, 1973). Viewpoint manipulations were used to assess visual sensitivity to rarely seen and frequently seen views of simple human actions.

In Experiment 1, participants viewed point-light depictions of actions previously generated by themselves, their friends, and matched strangers. These actions were depicted from egocentric, or first-person, and allocentric, or third-person, viewpoints. Performance in an identity discrimination task indicated that participants were able to identify actions previously performed by themselves and, to a lesser extent, the actions of their friends, from allocentric views but not from egocentric views. To determine whether this result simply reflected a perceptual inability to organize point-light displays seen from egocentric views, Experiment 2 assessed observers' ability to identify the actions, rather than the actors, portrayed in the same stimuli. These results indicated that observers could perceptually organize egocentric views of point-light displays for the purpose of action but not actor identification. Experiment 3 involved a manipulation of viewpoint frequency across two allocentric views. People very rarely see themselves from behind. If visual sensitivity to self-generated actions depends on visual experience, then observers should demonstrate greater visual sensitivity to self-generated actions viewed from the front than viewed from the back. The results indicated no significant difference in visual sensitivity to front and back views of self-generated actions. Thus, when visual experience and motor experience are decoupled through manipulations of viewpoint, visual experience appears to be unrelated to visual sensitivity to human motion, at least as measured by identity discrimination tasks. Instead, the current results are consistent with the hypothesis that visual sensitivity to one's own actions reflects the impact of motor constraints on visual processes (Knoblich & Flach, 2001; Knoblich & Prinz, 2001; Loula et al., 2005).

Although perceptual learning defines many perceptual and cognitive processes, it does not appear to define the perceptual ability to identify one's own actions. Yet, the finding that observers demonstrate greater visual sensitivity to allocentric views of the movements of their friends than to the movements of strangers indicates that visual experience must play some role in the visual analysis of human action. Indeed, previous research supports the importance of visual experience in biological motion perception (e.g., Bulthoff et al., 1998; Giese & Poggio, 2003; Jacobs & Shiffrar, 2005; Johansson, 1973; Loula et al., 2005). For example, visual sensitivity to a friend's action reflects the frequency with which one has viewed that friend perform that particular action (Jacobs et al., 2004). However, observers have substantially more experience watching their friends from the back than watching themselves from the back. Yet, visual familiarity does not appear to be associated with visual sensitivity to back views of oneself in action.

The finding that visual sensitivity to self-generated actions is not mediated by viewpoint-specific perceptual learning is also consistent with recent findings by Casile and Giese (2006). These researchers taught blindfolded subjects to produce a new action and subsequently tested subjects' visual sensitivity to point-light versions of that newly learned action and to similar, unlearned actions. Visual sensitivity to the motorically learned, but unseen, actions was higher than sensitivity to unlearned actions. Such results demonstrate a direct influence of acquired motor programs on action perception that is independent of visual learning (Casile & Giese, 2006).

It is interesting to note that neural activity in the extrastriate body area, or EBA, differentiates allocentric and egocentric views of static body images. However, this area does not respond differentially to static views of one's own body and other peoples' bodies (Chan, Peelen, & Downing, 2004). It is tempting to wonder whether this combination of response characteristics reflects the fact that observers usually experience egocentric views of their own bodies and allocentric views of other people's bodies. Indeed, identity is usually confounded with body view (looking at oneself in a mirror poses an intriguing exception). If so, then the poor identification performance found with egocentric views in Experiment 1 might be related to the difficulties that observers have in determining whether nearby limbs (Botvinick & Cohen, 1998) and nearby actions (Van den Bos & Jeannerod, 2002; Wegner et al., 2004) belong to their own bodies. On the other hand, activity in other cortical areas, such as the posterior region of the Superior Temporal Sulcus, does vary as a function of whether observers view their own actions or the actions of others (Hietanen & Perrett, 1996). Thus, integrated activity across multiple neural areas known to be involved in the visual analysis of human motion is needed to explain the current behavioral results.

Altogether, the current studies suggest that enhanced visual sensitivity to self-generated actions (e.g., Beardsworth & Buckner, 1981; Knoblich & Flach, 2001; Knoblich & Prinz, 2001; Loula et al., 2005) cannot be attributed to visual learning. To the extent that visual sensitivity to self-motion depends on perceptual learning, this sensitivity should increase with increases in visual familiarity. Yet, the results of the current studies contradict this prediction. Instead, they lend support to the hypothesis that motor experience defines visual sensitivity to self-generated action. Note that participants in these experiments had no difficulty identifying actions that they had previously performed when those actions were viewed from a third-person perspective. It has been argued that individuals come to represent themselves by interacting with other people and by learning how others perceive them (Neisser, 1991). The patterns of performance reported here may reflect the perceptual precursors to this social process.

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