
The visual perception of dynamic body language

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5.1 Introduction

Traditional models describe the visual system as a general-purpose processor that analyzes all categories of visual images in the same manner. For example, David Marr (1982) in his classic text *Vision* described a single, hierarchical system that relies solely on visual processes to produce descriptions of the outside world from retina images. Similarly, Roger N Shepard (1984) understood the visual perception of motion as dependent upon the same processes no matter what the image. As he eloquently proposed, “There evidently is little or no effect of the particular object presented. The motion we involuntarily experience when a picture of an object is presented first in one place and then in another, whether the picture is of a leaf or of a cat, is neither a fluttering drift nor a pounce, it is, in both cases, the same simplest rigid displacement” (p. 426). This traditional approach presents a fruitful counterpoint to functionally inspired models of the visual system. Leslie Brothers (1997), one of the pioneers of the rapidly expanding field of Social Neuroscience, argued that the brain is primarily a social organ. As such, she posited that neurophysiologists could not understand how the brain functions until they took into consideration the social constraints on neural development and evolution. According to this view, neural structures are optimized for execution and comprehension of social behavior. This raises the question of whether sensory systems process social and non-social information in the same way.

Extensive research has addressed the communication of social information by facial and hand gestures (e.g. Streeck 2002; Haxby and Gobbini 2007). The goal of this chapter is to address another conveyer of social information; that is, the actions of the human body. In the popular press, numerous books have purportedly identified the precise information communicated by various body postures. For example, in *The Definitive Book on Body Language* (Pease and Pease 2006), the authors claim to have discovered the body postures that communicate lying, bluffing, and sexual interest. While enticing, the conclusions reported in the popular press are generally not grounded in methodologically rigorous experiments. Nonetheless, the research described below is in agreement with the popular press’s take on the perception of “body language” on one fundamental point; namely, that the human body communicates extensive social information.

The goal of this chapter is to provide a state-of-the-art review of psychophysical and neurophysiological findings regarding the perception of social information from large-scale

bodily movements. This topic is described as dynamic body language because of the emphasis on whole body actions rather than static body postures. For a discussion of the information communicated by smaller-scale actions, such as hand gestures, the reader should turn to the contributions of Poggi and Pelachaud, Streeck, and Duncan in this volume.

5.2 What defines a human body?

For the moment, let us put aside the question of whether human action communicates perceptible social information. Indeed, one cannot begin to address that question without first identifying those factors that the visual system uses to identify the presence of a human body. Simply put, observers must determine whether they see another person before they need to worry about what social cues can be extracted from that person's actions. It is of course worth considering whether the visual system analyses human movement differently from object movement. If the visual system used the same motion analyses for humans and non-human objects, as traditional theories of the visual system predict, then observers could forgo a differentiation stage (human versus non-human) and begin by directly analyzing cues to social information. However, recent brain imaging data indicate that while the human and object movement are initially analyzed by the same brain regions, analyses of these two categories of motion diverge about 200ms after stimulus onset (Virji-Babul *et al.* 2007). Thus, the visual system does differentiate between human and non-human motions fairly rapidly.

5.2.1 Does the visual system analyze human motion differently from object motion?

By definition, motion is a change in location over some period of time. To perceive movement, our visual system must interpret luminance changes across space and across time. Therefore, one way to compare the visual analysis of human and non-human motions is to examine how each is analyzed over space and time.

5.2.1.1 Integration across space

One of the difficulties inherent to the integration of visual information across space is the aperture problem. The aperture problem occurs whenever large perceptual stimuli must be understood from small measurements. In the case of the visual analysis of movement, initial measures are made by neurons with small receptive fields (e.g. Hubel and Wiesel 1968) that respond to tiny image subregions. To calculate the movement of real world objects, the visual system must combine and segment these small measurements. This situation is analogous to John Godfrey Saxe's (1855) rendition of the classic Indian tale of six blind men feeling an elephant in order to identify it. One feels only the tail, another a tusk, yet another a knee, another the trunk, the fifth feels the ear, and the sixth man feels the elephant's side. None of the men can identify the elephant by generalizing his individual tactile percepts. Instead, a complex, higher-level integration of the men's collective experiences would be needed to identify the elephant. In the same way, no individual neuron in an observer's visual system can identify a real object's motion. Because all known visual systems, whether biological or computational, have neurons

with receptive fields that are limited in size, this measurement ambiguity has been extensively studied (e.g. Hildreth 1984; Wallach 1976).

How does the visual system compute accurate object motion from local measurements? Obviously, local measurements need to be integrated into a coherent whole. But how? One class of global processing models requires the comparison of motion measurements across rigidly connected edges that have different orientations (e.g. Adelson and Movshon 1982). Conversely, one classic local model relies on the motion measurements taken from edge discontinuities, such as endpoints and corners, that indicate where one object ends and the next object begins (e.g. Hildreth 1984). In fact, the human visual system appears to use both global and local motion processes under different conditions (Shiffrar and Lorenceau 1996).

Are the same motion processing strategies used during the analysis of human motion and object motion? The answer is no. When observers view simple objects, such as squares, cars, and scissors, under conditions that are subject to the aperture problem described above, their percepts indicate the use of local motion processes (Shiffrar and Pavel 1991; Shiffrar and Lorenceau 1996). Conversely, when observers view human motion through apertures, their percepts indicate the use of global motion processes (Shiffrar *et al.* 1997). Interestingly, these global analyses appear to be dependent upon the physical plausibility of an observed action. When observers view a person walking with impossibly fast or impossibly slow gaits, their percepts indicate local interpretations (Shiffrar *et al.* 1997). Conversely, observers use global processes to interpret physical possible gaits.

Point-light displays can also be used to examine how the visual system integrates motion measurements across space. These displays are constructed by attaching small markers or point-lights to the major joints of moving actors (see Figure 5.1A). The actors

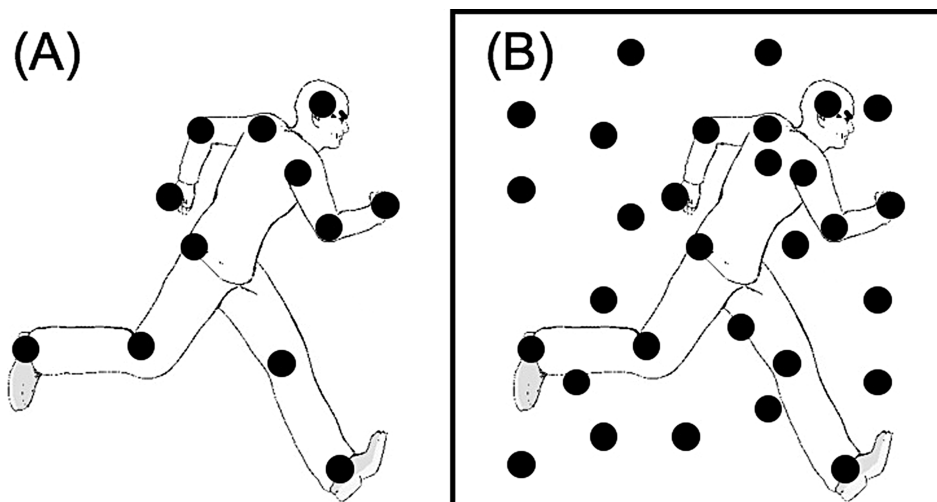


Figure 5.1 (A) A static depiction of a point-light runner. The outline of the person is not visible in the displays and is shown here for illustration purposes only. When viewed statically, the displays cannot be interpreted. However, once set in motion, observers rapidly detect the presence of a running person. (B) A static depiction of a point-light runner presented within a mask.

are filmed so that only the point-lights are visible. When these highly degraded displays are set in motion, observers readily perceive human motion (e.g. Johansson 1973, 1976). Yet, static point-light displays are almost impossible to interpret. Importantly, when a point-light defined person appears within a point-light mask, as shown in Figure 5.1B, observers can reliably detect the person (e.g. Bertenthal and Pinto 1994; Cutting *et al.* 1988). Since the points in the mask have the same size, luminance, and velocities as the points defining the walker, local analyses of the motions of individual points cannot be used to detect the walker. Because only the global configuration of the locations of multiple points distinguishes the walker from the mask, detection of point-light walkers in a mask must rely on global or large-scale motion processes (Bertenthal and Pinto 1994). When the same masking technique is used with non-human, inanimate motions (e.g. Hiris *et al.* 2005), observers' demonstrate marked decrements in their ability to detect these figures. This pattern of results suggests that observers are better able to integrate human motion than non-human motion across space.

5.2.1.2 Integration across time

Other research indicates that the human visual system integrates human and non-human motions differently over time. Temporal aspects of motion perception have traditionally been examined with studies of apparent motion. Apparent motion is the illusory perception of movement from rapidly flashed static images (Korte 1915; Wertheimer 1912). The visual perception of human motion and object motion in apparent motion displays differs. For example, when naïve observers view two different images of a person in two different poses (see Figure 5.2), they generally perceive the shortest possible path

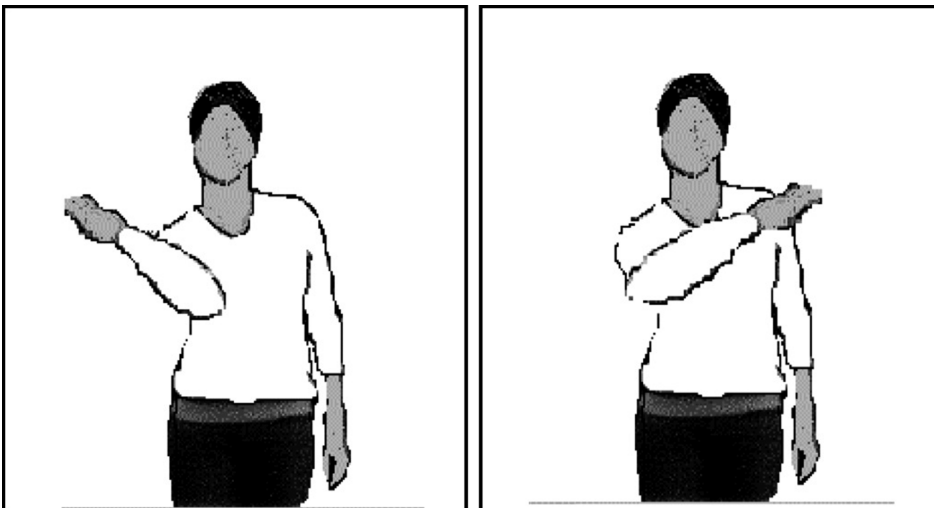


Figure 5.2 Two frames from an apparent motion display. The frame on the left depicts a woman with her right hand positioned on the right side of her head. The next frame illustrates the same woman with her right hand positioned on the left side of her head. When these two images are flashed in rapid alternation, the woman's hand appears to move through her head. However, as the temporal display rate slows, the woman's hand increasingly appears to move around her head.

connecting those poses, even if that path describes a physically impossible motion, such as a hand translating through a person's head. This is consistent with the "shortest-path constraint" in apparent motion and is found with human and non-human images alike (Burt and Sperling 1981; Shiffrar and Freyd 1990). However, when pictures of the human body are presented at temporal rates that are consistent with the temporal range of normal human actions, observers tend to perceive paths of apparent motion that are consistent with the biomechanical constraints on human movement (Shiffrar and Freyd 1990, 1993). Conversely, when objects are shown at these same temporal rates, observers always perceive the shortest possible paths of apparent motion. This pattern of results suggests that human movement is analyzed by motion processes that operate over relatively large temporal windows and that take into account the biomechanical limitations of the human body.

5.2.2 What cues does the visual system use to identify the presence of another person?

The research summarized above indicates that the visual system analyses human and non-human motions differently. But how does the visual system determine whether an image depicts a moving human body? The research described below indicates that both form and motion information is critical for this determination.

The structure of visual information appears to determine how a visual image will be analyzed. One way that the visual system determines whether an image contains a human form is by searching for structural matches between that image and the observer's representation of his or her own body (Shiffrar 2006). These representations are known as body schema and consist of an internal, multimodal representation of the relative locations of an individual's own body parts. Body schemata do not always match the physical structure of a person's body. For example, if someone loses a limb during a car accident, their body schema may fail to change accordingly. When such a mismatch occurs, people can experience a phantom limb, that is the sensation that an absent limb is still attached to their body (Brugger *et al.* 2000). Phantom limbs can also occur in people having congenitally absent limbs (Brugger *et al.* 2000) indicating that some individuals have body schema that permanently mismatch their physical bodily structure. Nonetheless, these body schemas are employed in the perception of other people's actions (Funk *et al.* 2005). For example, human imaging data indicate that when observers view pictures of the human body in an apparent motion display, neural activation increases in those areas involved in the observer's own body representation as well as in areas involved in visual motion perception and action planning (Stevens *et al.* 2000). As described in greater detail below, these and other studies suggest that the visual system looks for matches between that observer's body schema and body-like structures in visual images.

The spatial relationships between motion and body structure also help to define the presence of another person. For example, one study compared visual sensitivity to the presence of point-light walkers in a mask (Figure 5.1B). Across conditions, the limbs of a point-light walker are relocated so that they are no longer consistent with the hierarchical organization of the human body. Detection performance in this task indicated that

perceptual sensitivity to the presence of human motion decreases whenever the locations of the point-lights deviated from their canonical locations (Pinto and Shiffrar 1999). Furthermore, apparent motion research indicates that a single moving limb is not sufficient to trigger the mechanisms underlying the perception of human motion (Heptulla-Chatterjee *et al.* 1996). This is likely because a single limb does not contain the hierarchical cues that define the structure of the human body.

Is it simply the presentation of a canonical human form that is the key? Another possibility is raised by theories of embodied perception. As will be elaborated below and in other chapters in this volume, theories of embodied perception argue that perception is body-dependent because observers use their own motor and kinesthetic experience to assist in the visual analysis of the outside world (e.g. Prinz 1997; Prinz, this volume; Sebanz and Knoblich, this volume). This approach raises the question of whether the visual system looks for image cues that match the observer's own body, rather than looking for some idealized human image. In one of many tests of this question, individuals born without hands were tested for their percepts of apparent hand rotations (Funk *et al.* 2005) using the methodology from Shiffrar and Freyd (1990) that was described above. The results indicate that perception of apparent hand rotation depended upon whether observers had a mental representation or "body schema" of their own hands. When an individual lacks a schema for his missing hands, he consistently perceived hand rotations in the same way that handed individuals perceive objects in apparent motion; namely, the shortest possible path of apparent motion is perceived at all temporal display rates—even when those paths are physically impossible. Conversely, when an individual born without hands nonetheless has schema for her missing hands, that person consistently perceived apparent hand rotations in the same way as "handed" control observers. That is, as the temporal display rate slowed, she and control observers increasingly reported the perception of biomechanically possible paths of apparent hand rotation. These results suggest that the determining factor in image analysis is the degree to which a visual image matches an observer's representation of his or her own body (Shiffrar 2006).

In addition to form cues, motion information also determines whether a visual image is analyzed as an object or an action. Once again, findings from the embodied perception literature are relevant here as numerous studies indicate that the perception of movements that an observer can produce differs from the perception of movements that the observer cannot produce. For example, the two-thirds power law describes the algebraic relationship between the instantaneous velocity and radius of curvature for human hand movements (e.g. Viviani and Stucchi 1992). Perceptual sensitivity is optimized for movements that are consistent with this law of human movement production (Viviani 2002). Furthermore, observers demonstrate greater visual sensitivity to point-light depictions of actions that they can perform than to depictions of actions that they have never performed (Casile and Giese 2006). The fundamental importance of the match between what is perceived and what can be produced is also evident in recent brain imaging data. For example, when ballet dancers view dances that they can perform and dances that they have never performed, different neural processes are invoked (Calvo-Merino *et al.* 2005).

The importance of an observer's motor capabilities on the visual analysis of human movement is further supported by research using moving observers. Walking observers, for example, demonstrate less visual sensitivity to point-light depictions of walking people than do stationary or bicycling observers (Jacobs and Shiffrar 2005). Furthermore, judgments of the perceived weight of a box being lifted by another person depend on the weight of the box being lifted by the observer (Hamilton *et al.* 2004). These results likely reflect competing demands for access to shared representations that code for both the execution and perception of the same action (e.g. Prinz 1997). In sum, one of the ways that the visual system determines whether an image depicts a person is the extent to which the motion cues in the image match the range of actions that the observer can perform.

5.3 What social information is visually communicated through bodily action?

5.3.1 Physical and psychological features

Once the visual system has determined that an image depicts a human body and has processed that image accordingly, what information is extracted? Extensive research has shown that observers can readily determine physical characteristics, such as gait speed (e.g. Jacobs and Shiffrar 2005) and gait direction (e.g. Thornton *et al.* 1998) from point-light displays of human action. Observers can also identify the type of action performed by a point-light person (Dittrich 1993; Johansson 1973, 1976). But can the human body communicate more complex, psychological information? The character Sherlock Holmes famously said, "I am a brain, my dear Watson, and the rest of me is a mere appendage" (Doyle 2002/1921). To the extent that this assertion holds true, the movements of Sherlock Holmes' body should have no communicative value—that is, they should tell you nothing about his psychological state. This proposition turns out to be false. People naturally communicate substantial information with their bodily postures (e.g. de Gelder and Hadikhani 2006), manual gestures (e.g. Streeck 2002), and whole body actions (e.g. Blake and Shiffrar 2007).

The list of social information communicated by whole body actions is vast. Observers demonstrate impressive levels of visual sensitivity to the gender of point-light walkers (Pollick *et al.* 2005). Even more intriguing is the finding by Ambady and her colleagues (1999) that observers can determine a moving individual's sexual orientation from a 10-second movie of the outline of that individual's moving body. Determinations of sexual orientation are at chance with static pictures. Other researchers have found that observers can readily and accurately assess another person's attractiveness, and potentially reproductive fitness, from motion cues alone (Brown *et al.* 2005). Furthermore, observers of point-light displays can readily identify a person's degree of openness (Brownlow *et al.* 1997), age and social dominance (Montepare and Zebrowitz-McArthur 1988), and vulnerability to attack (Gunns *et al.* 2002). Obviously, there is much that is communicated with dynamic body language.

People also express their psychological intentions through their bodily actions and observers are sensitive to those cues. For example, in one study, individuals were

asked to walk, jump, and sit in a manner that was either consistent or inconsistent with their own gender. When naïve observers viewed point-light displays of these deceptive actions, they readily detected the deceptive intentions of the individuals (Runeson and Frykholm 1983). In this same set of studies, individuals were asked to lift an empty box normally and in a manner that suggested that the box was heavy. Again, observers accurately detected the deceitful lifts. This finding is also interesting in relationship to a recent study of observers with no sense of cutaneous touch or proprioception. When asked to view and judge short movies of a hand picking up a box, these observers demonstrated selective deficits in their ability to detect misjudgments in the lifter's assessment of the weight of a box (Bosbach *et al.* 2005). Consistent with theories of embodied perception (e.g. Prinz 1997), this finding suggests that observers use their own bodily senses during their perception of human action. Bodily influences on the visual perception of intention are also suggested by a study of the perception of point-light basketball players. This work suggests that the ability to detect whether or not a basketball player intends to pass a basketball depends upon the observer's level of motor experience passing a basketball (Sebanz and Shiffrar 2007).

The accurate perceptual detection of another person's affective state is important for the establishment of successful social interactions. Previous research indicates that bodily action alone, that is in the absence of any facial or auditory cues, is sufficient for the perception of emotional state. For example, observers can readily identify the emotions being portrayed by the whole body movements of a point-light actor (e.g. Atkinson *et al.* 2004). Furthermore, observers can discriminate the emotional state of a point-light defined arm knocking on a door (Pollick *et al.* 2001). Social context facilitates the perception of emotion from whole body actions. In one such study, point-light displays of an actor were created while that actor was engaged in an emotional interaction with another person. Perceptual sensitivity to the actor's emotional state depended upon whether the other person was also displayed. Specifically, emotion perception was best when observers could see both of the point-light actors (Clarke *et al.* 2005). Thus, not only can observers perceive an individual's emotional state from whole body motions, their percepts depend upon the social context. Neurophysiological evidence supports the tight connection between emotional processes and action analyses. The posterior region of the superior temporal sulcus, or STSp, is thought to play a core role in the visual analysis of human movement (e.g. Grossman *et al.* 2000). Interestingly, the STSp responds more strongly during the perception of emotional gestures than during the perception of instrumental gestures (Gallagher and Frith 2004). Indeed, the STSp plays a critical role in the perception of socially relevant information (e.g. Allison *et al.* 2000).

5.3.2 Identity

Accurate identification of oneself and others is a fundamental prerequisite for successful communication. Indeed, some developmental psychologists argue that identity perception plays a foundational role in the development of a child's sense of self (e.g. Lewis 1999). Human observers can accurately identify their friends from movement cues alone. For example, individuals can recognize their own gaits and the gaits of their friends from

point-light displays (e.g. Beardsworth and Buckner 1981; Cutting and Kozlowski 1977; Jokisch *et al.* 2006). Again, the observer's own body has a significant impact on their perception of human motion. This conclusion comes from studies showing that observers have the greatest perceptual sensitivity to actions that they themselves have produced. For example, in one study, participants were filmed while they threw darts at a dartboard. Sometime later, they viewed movies of the initial portions of their own dart throws and other people's dart throws. When asked to predict where each dart would land on the dartboard, participants' predictions were most accurate when they viewed their own dart throws (Knoblich and Flach 2001). In another study, participants were filmed while performing a variety of actions, such as jumping in place and boxing. The films were converted into point-light movies. These same participants later viewed pairs of point-light movies and reported whether each pair depicted the same person or two different people. Identity discrimination performance was best when participants viewed point-light displays of their own actions (Loula *et al.* 2005). Subsequent studies ruled out the possibility that enhanced visual sensitivity to self-generated actions results from visual experience (Prasad and Shiffrar 2007). Instead, the above results suggest that each individual's visual system is optimized for the perception of his or her own actions because each individual's motor system contributes to their perception of human movement.

5.4 Is the visual extraction of social information from bodily action automatic?

The studies reported above suggest that the human visual system is tuned to extract socially relevant information from the actions of the human body. Is social information automatically extracted from dynamic body language? Or, must observers consciously search for that information? Several studies suggest that social analyses are inherently interconnected with action perception such that one cannot occur without the other. Some of those studies are outlined below.

5.4.1 Social context modulates the visual perception of apparent human motion

As described in the introductory section of this chapter, traditional models of the visual system assume that visual perception influences social processes while social processes have no impact on visual perception. Contrary to this classic approach, recent neurophysiological evidence indicates that the neural areas involved in social cognition are tightly coupled with the neural areas involved in the visual perception of action (e.g. Adolphs 2001). Furthermore, activity in these "social cognition" areas increases during the passive observation of human actions directed towards another person but not during the observation of those same human actions in isolation (Iacoboni *et al.* 2004). This combination of results suggests that social processes may automatically contribute to the visual perception of human motion.

To determine whether social processes constrain the visual perception of dynamic body language, naïve participants viewed a set of two frame apparent motion displays

that depicted simple actions such as reaching, pointing, and kicking (Figure 5.3). The displays were edited so that each action appeared in static, pictorial contexts that were either social (directed towards another person) or non-social (directed towards an object) in content. Participants were lead to believe that they were contributing to a study comparing the dynamic image quality of different computer monitors. They then viewed each of the simple actions in either a social context or a non-social context and rated the quality of the movement they perceived. Participants who viewed the actions within a social context rated the apparent motion displays as conveying more motion than participants who viewed the same actions in a non-social context (Chouchourelou and ShiffRAR 2007). Indeed, actions directed towards objects were perceived differently from actions directed towards another person. This is consistent with the hypothesis that the neural analysis of object-directed actions differs from the analysis of person-directed actions (Jacobs and Jeannerod 2003). Thus, social processes, *per se*, spontaneously influence the visual analysis of human action.

5.4.2 Emotion modulates action detection

Is the visual analysis of human actions similarly modulated by the emotional content of those actions? A consideration of the neuroanatomical connections between visual and emotional areas suggests that such modulation is possible. Specifically, the STSp, described above as a neural area that plays a critical role in the visual perception of human movement (Grossman *et al.* 2000), is extensively interconnected with the amygdala, a center for emotion processing. To the extent that amygdala activity influences STS activity, one would expect to find systematic differences in the visual detection of emotional actions. The results of a psychophysical study are consistent with this prediction. In this study, point-light walker movies were constructed that depicted walking people in one of five different emotional states: happy, sad, neutral, angry, and fearful. These point-light light walkers were placed in specially constructed masks and participants tried to detect the presence of a point-light person in each mask. Detection performance was systematically modulated by the emotional content of the gaits. Specifically, participants demonstrated the greatest visual sensitivity to the presence of angry walkers (Chouchourelou *et al.* 2006). This finding is particularly interesting because many researchers have argued that the amygdala is most responsive to potentially threatening stimuli (Amaral *et al.* 2003; Whalen *et al.* 2004). An angry person is clearly a threatening stimulus. Thus, these results suggest that emotional processes automatically contribute to and indeed help to define visual sensitivity to the actions of other people.

5.5 Conclusion

The human visual system must be understood as an inherently social organ that allows for the rapid and accurate detection of socially relevant information (Brothers 1997). As people go about their daily lives, their bodily actions express a plethora of physical and psychological information. The results described above indicate that human observers read this bodily language with ease. This perceptual sensitivity cannot be understood

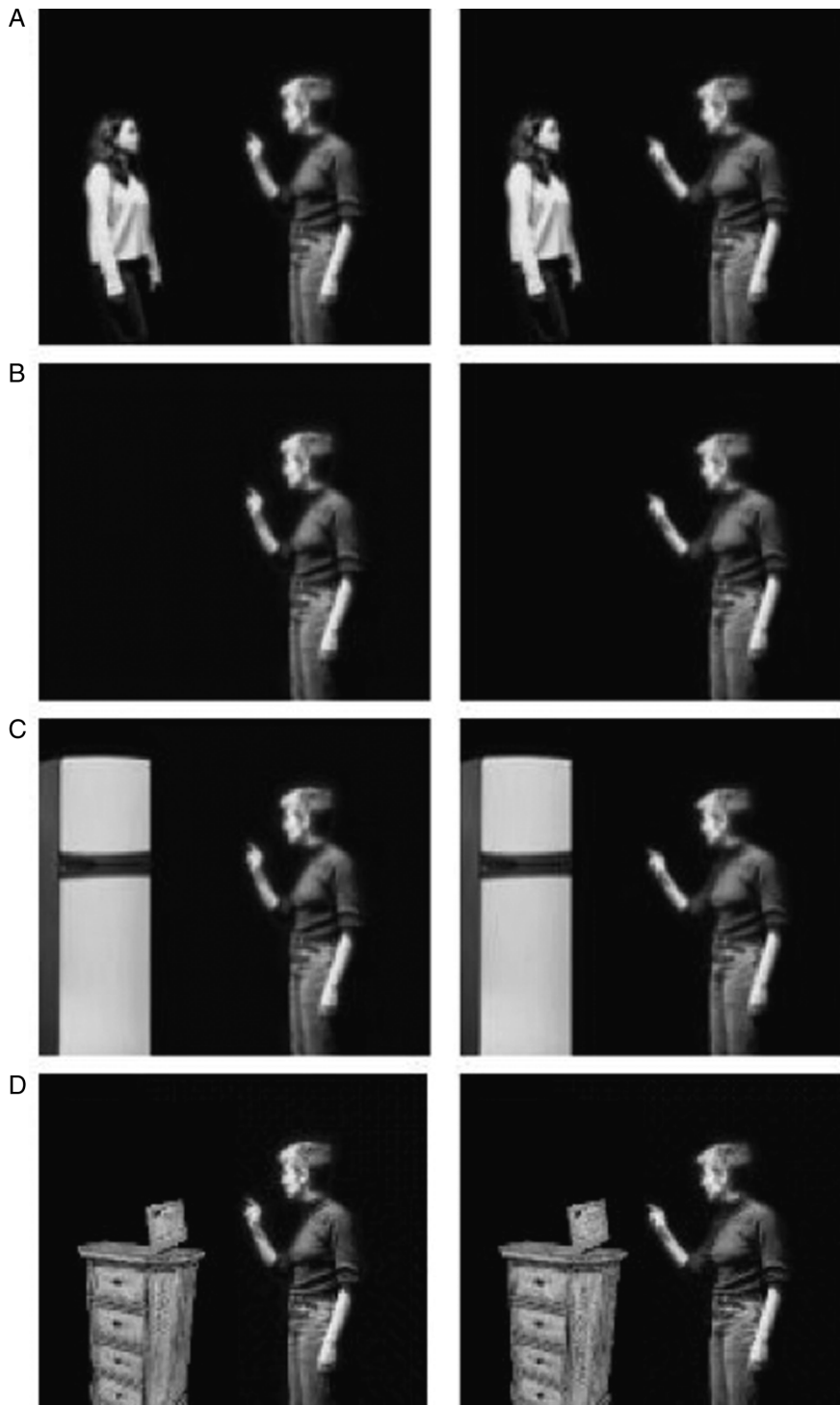


Figure 5.3 Four pairs of apparent motion stimuli. (A) The top pair illustrates a dynamic speaker on the right and a static listener on the left. In the subsequent three pairs, the static listener is either removed (B) or replaced with a static object (C, D). Observers viewed pairs of such stimuli and reported how much motion they perceived. Even though the amount of physical movement was identical in all four conditions, because only the speaker moved, observers perceived more motion when actions appeared in social contexts (A).

from the study of sensory mechanisms alone. Instead, the visual perception of human actions is deeply constrained by motor, social, and emotional mechanisms.

The human visual system can no longer be seen as a general processor that analyzes all images in the same manner. Visual processing depends upon the similarity between perceived image features and features of the observer's own bodily and motor representations. When a match is found, more global processes are engaged. Such expanded analyses of human action can incorporate motor, social, and emotional processes and thereby allow human observers to perform remarkably fine-tuned assessments of the people around them. Thus, our ability to perceive body-based information depends upon our detection of the numerous similarities between ourselves and others. This brings us full circle as embodied social beings.

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