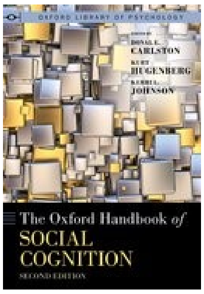

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CHAPTER

9 Perception and Action

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Abstract

Cognition would be maladaptive, energy consuming, and wasteful if not for the processes of perception and action to sense the surrounding world and act within it. Yet, the importance of perception and action for understanding cognition is much debated. This chapter outlines a variety of ways that perception, action, and cognition are not independent processes merely feeding information from one to the other, but intertwined and functionally connected. The consequences of this functional connection are seen in a variety of phenomena. We start with the dependency of the visual system on action and then describe Gibson's ecological approach to psychology, including the role of action in perceiving and the perception of affordances. We then cover how perception of others' actions and its impact on one's own cognition and movements. We finish with the action-specific approach to perception. Perception and action influence each other, and these influences have consequences for social cognition.

Keywords: perception–action coupling, visual cognition, ecological psychology, affordances, motion perception

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People have a sense that their perception is objective and veridical, that they see the world and the people in it as they truly exist. Philosophers as early as Plato realized that this impression is misleading and hides the true inner workings of the perceptual systems. One such example relates to the influence of action on perception. Although it may feel as though action follows perception in a sequential order, the relationship between action and perception is reciprocal. Action influences perception in meaningful ways. To the extent that social cognition is concerned with perception—either perception of other people or perception of objects in the context of others—it is important to understand the influence that action can have on perception. In this chapter, we review several of these influences to illustrate many ways that perception and action are connected.

At a fundamental level, one could make a strong argument for why perception and action are important for understanding social cognition. Interestingly, a starting point for the argument has been used to convince psychologists of the importance of understanding physical actions for understanding psychological processes; the argument is that if humans did not have an action system, they would not be able to translate perception and other mental processes into actual changes in the environment (Fiske, 1992; Wolpert, 2011). If not for this ability, much of our mental activity would be rendered useless. Thus, we must understand p. 246 perception and action to understand cognition. We could extend this argument to social cognition as ↳ well. It should be noted that much of our social development originally takes place in the form of perceptual and physical interactions with our parents and caregivers. Basic mechanisms linking perception and action early in life may scaffold more complex social cognitions later in life. At least some of the mechanisms for social cognition rely on the perception of other people's actions, so it is worthwhile to consider how perception and action relate.

Perception Depends on Action

There is a nontrivial sense by which perception depends on action. It is only through actively moving our sensory organs that we can detect the surrounding environment. The demonstrations of this phenomenon are spectacular. One comes from Yarbus (1967), who wanted to determine whether eye movements were necessary to be able to see. How does one divorce eye movements from the image projecting on the retina at the back of the eye? Yarbus, cleverly if not painfully, used a suction cup to yoke the stimulus to eye, thereby creating a stable image on the retina regardless of how the eye moved (see Figure 9.1). He found that rather than perceiving the image itself, participants perceived nothing at all. He concluded that eye movements and their corresponding changes in retinal stimulation were necessary for perception. Thus, at a fundamental level, perception depends on action.

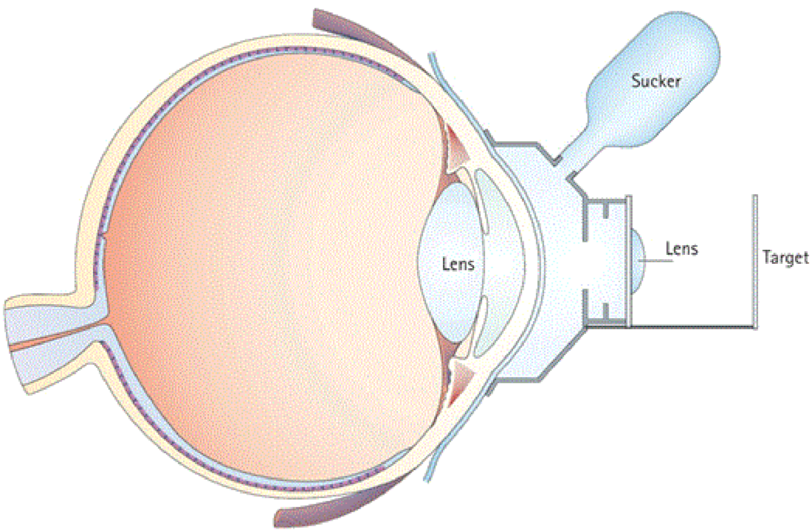

Figure 9.1 Schematic of suction cup used by Yarbus (1967) to stabilize the image of the target independent of eye movements. Image from Martinez-Conde et al. (2004). Reprinted with permission of Macmillan Publishers Ltd.

But perception depends not just on eye movements, but also on learning how perception and action are entrained. In one experiment (Held & Hein, 1963), kittens were raised from birth in dark, lightless rooms. Their movements were unconstrained but had to be performed without vision. Their only exposure to light occurred when they were placed in the kitten carousel, a contraption in which two kittens were placed in separate baskets that were linked to a rotating pole in the middle, just like a regular carousel (see Figure 9.2). The baskets were made of metal. One basket had holes in the bottom, which allowed the kitten's paws p. 247 to touch the ground. As this kitten walked, it moved itself and the basket forward, causing the center ↳ pole to rotate. We refer to this kitten as the *active* kitten. The other basket, which held the *passive* kitten, had a flat bottom. This allowed the kitten to walk normally, but its paws slid along the bottom of the basket and did not propel it forward. Instead, the basket's movements were perfectly yoked to the movements of the active kitten. The brilliance of this setup is that the visual information received by both the active kitten and the passive kitten was the same. Yet, for the active kitten, the visual information was linked to its movements, whereas for the passive kitten, there were only coincidental links between its movements and the incoming visual information. Thus, both kittens had similar motor experience (albeit all in the dark) and similar visual experience, but differed with respect to the link between perception and action. After several months, the researchers tested the kittens in a variety of tasks. One was to measure whether the kittens extended their paws as they were being placed onto a table, which is a natural response for cats. Another was to put them in the middle of a visual cliff (cf. E. J. Gibson & Walk, 1960; see also Figure 9.3A). A food reward was placed on the floor, and the researchers measured how often the kittens went down on the shallow (visually safe) side versus the deep (visually unsafe) side. The active kittens performed well on all tasks, whereas the passive kittens acted as if they were blind. Their performance was at chance. They did not know how to perceive; they could not make meaning out of the visual stimulation. The researchers then gave the passive kittens 72 hours of unconstrained movements in a lit environment and tested them again. Now the passive kittens performed well: they extended their paws and chose to descend the safe side. In other words, once these passive kittens had an opportunity to experience the link between their own movements and the corresponding visual information, they developed the ability to perceive normally.

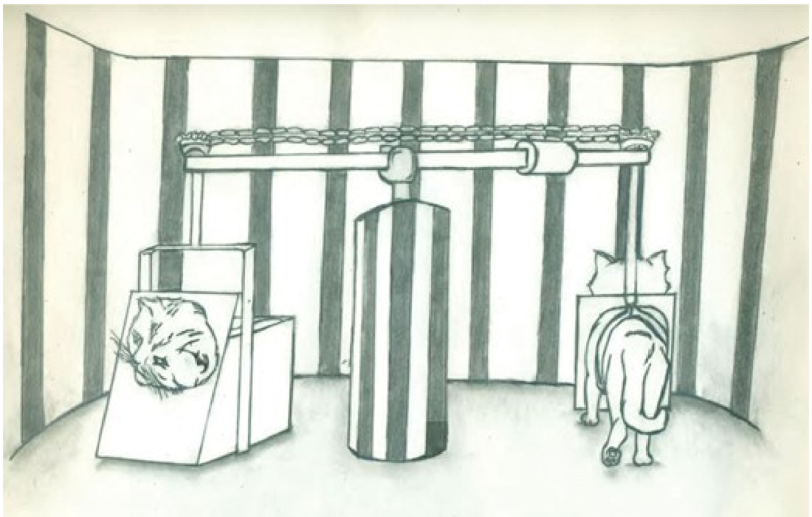

Figure 9.2 Illustration of the kitten carousel used by Held and Hein (1963). The active kitten is on the right, and the passive kitten is on the left. Drawing by Katherine Becker.

That perceiving depends on the link between perception and action continues throughout development, as p. 248 demonstrated using the wonderful gadgetry in the laboratory of Karen ↳ Adolph (see Figure 9.3). She showed that each time a young child learned a new movement, such as when babies go from sitting to crawling or from crawling to walking, they needed to learn how to perceive again (Adolph, 2000, 2008). Babies who were skilled crawlers could perceive which hills were too steep to descend and which hills afforded crawling. But when these babies learned to walk, they no longer knew how to perceive the hills and p. 249 would plunge down hills far too steep to afford descending. A claim to fame in Karen Adolph's lab is that ↳ even though all the experiments are designed to create many opportunities for babies to fall, they have never dropped a single child. Another claim to fame is the diverse and compelling demonstrations showing the necessary link between acting in the world before being able to perceive it. As people change, in their bodies or in their body's capabilities, they must experience action and the resulting visual consequences to relearn how to perceive (Franchak et al., 2010).

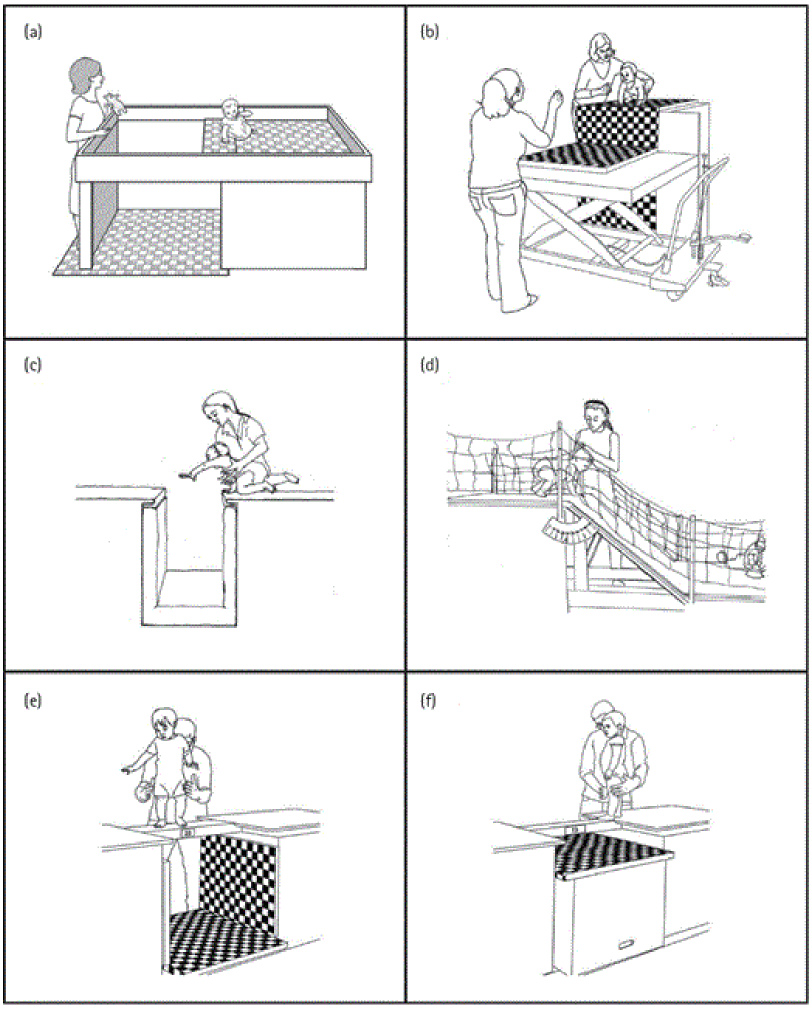

Figure 9.3 Illustrations of the methodological setups in Karen Adolph's laboratory. These gadgets were used to test infants' perception of depth (A, B), gaps (C), slants (D), and bridge widths (E, F). Image from Adolph et al. (2014).

Even once the perception–action link has been learned, the perceptual systems are not passive recipients of information but rather engage in actions to specifically seek it out. The impression given by typical vision research, with head movements constrained by chin rests and limited to no opportunity to engage in meaningful ways with the environment, is that the perceptual system is a passive recipient of incoming information. Despite this impression, the truth is that the perceptual systems are active. Perceivers actively move their eyes to dictate the incoming information (Hayhoe & Ballard, 2005). Perceivers actively tilt their heads to orient their ears toward a sound and actively sniff with their noses to enhance the richness of the smell of a wine or a delicious dish. The kinds of movements one makes with one's hands dictates the specific tactile information that will be processed, such as rubbing a surface to detect texture and pressing on a surface to detect temperature (Lederman & Klatzky, 1987). Understanding how a perceiver detects information about objects, or about other people, requires understanding how the perceiver actively seeks information.

Ecological Approach to Perception

Research in vision science has operated under one of two major theoretical positions, one stemming from von Helmholtz (1867) and another from J. J. Gibson (1966). Much research in vision occurred under the umbrella of ideas from Hermann von Helmholtz that the information for vision was sparse, leading to an ill-posed problem and requiring unconscious inferences about what was seen. To unpack this, the idea was that the information reflecting into the eye at any moment could have arisen from an infinite number of scenes, thereby forcing the perceiver to essentially guess what they were looking at. These guesses were supposedly educated guesses based on knowledge of the world, a process von Helmholtz (1867) termed unconscious inference. While research in vision continues in this vein, recently reignited with investigations into priors and the perceptual systems as Bayesian integrators, another approach has instead focused on the richness of the visual information.

When researchers took observers out of artificial and constrained laboratories and into an ecological context, several new insights and phenomena emerged. James Gibson was one of the first to point out that the information for vision was not a single retina image but rather an everchanging flow in the optic array (J. J. Gibson, 1966). From this optic flow, the perceiver can extract invariants that specify the layout of the surrounding environment. With this conceptualization, Gibson rejected the notion of an impoverished stimulus and the need for inferences.

One of the points being emphasized here is the richness of the information available to the perceiver. In J. J. Gibson's case, this richness conveyed the surrounding surfaces. With respect to social cognition, there is richness in the information available about other's actions, beliefs, and intentions. There is likely more richness in this information than is currently realized by researchers. An example is that the kinematics of a person's movements can convey not only the movement but also the intention that drove the movement in the first place (more about this in the section "Actor-Specific Inferences Based on Observed Action Kinematics"). Researchers should consider not only how people process information but also all possible sources for information relevant for social cognition.

 Another major insight from Gibson was the notion of affordances (J. J. Gibson, 1979). Affordances are what the environment offers, for good or ill, to the perceiver. According to Gibson, affordances are the primary object of perception. This means that instead of identifying objects or colors or shapes or sizes, the perceiver first and foremost identifies the affordances, such as the possibilities for action. A sidewalk affords walking. A street also affords walking but affords greater risk of being hit by a car as well. A path along a cliff affords walking and the danger of falling. It is important to note that while the design of objects should take affordances into account (Norman, 1988), affordances are different than intended design. A chair is designed for sitting and also affords sitting, but a chair has many other affordances as well, such as standing on or hiding under or using it to block a door. Another important point is that affordances depend on the perceiver–environment relationship. A rock only affords throwing if it is the right size and weight for that perceiver. A rock that is too heavy and too big for a child but not for an adult affords throwing only for the adult. In addition to perceiving one's own affordances, people can also perceive the affordances for other people.

With respect to social cognition, a point to emphasize is that perception is relational. People perceive affordances, which reflect the mutual relationship between the perceiver and the environment. Perception is thus specific to the perceiver but is not subjective; rather, perception is objective with respect to the perceiver–environment relationship. Social cognition is also likely to be relational. The relationship between the perceiver and others will dictate the affordances that are available to be perceived (Marsh, Johnston, et al., 2009). Dyadic relationships change the way people coordinate their actions (Marsh, Richardson, et al., 2009). Such coordination depends on people being sensitive to affordances for themselves, sensitive to the abilities of others, and sensitive to the new affordances available when acting as part of a team (Marsh & Meagher, 2016). Whereas a large or heavy object may not afford lifting by one individual, it may become liftable by two or more people, thus creating new affordances. These joint affordances (Knoblich et al., 2011) influence how we perceive the world. Indeed, when people judged the weight (in pounds) of boxes they anticipated having to lift later, they estimated the boxes to be lighter when they anticipated lifting them with someone versus when they anticipated lifting them alone. In addition, the boxes also appeared to be heavier when the lifting was to be done with a person of diminished health or strength resulting from injury (Doerrfeld et al., 2012). Thus, perceived joint affordances change our perception of our environment.

Perceived joint affordances not only change perception, but also change transitions between different types of actions. For example, imagine two people working in a factory at a conveyor belt used to transport wooden planks of varying lengths. Depending on a plank's length, the workers may lift short planks individually, but longer planks must be carried by two people. Interestingly, in this kind of context, the switch from one mode to the other (individual to joint and vice versa) has been shown to depend on the relationship between the plank's length and the pair's joint arm span (Richardson, Marsh, & Baron, 2007). Thus, affordances in this case are truly present at a level that extends beyond a person's individual body. Instead, joint affordances may arise through the embodied characteristics of joint actors (van der Wel et al., 2016). Engaging in joint action based on joint affordances vastly increases the number of action possibilities.

Affordances, in the strict sense that J. J. Gibson (1979) intended, refer to information that is in the optic array, or maybe the global array (Stoffregen & Bardy, 2001). However, the idea of affordances signaling possibilities for action has been extended to many domains, including opportunities provided by one's job in the workplace. Diekman and her colleagues have investigated how the affordances of one's position lead to a sense of belonging, particularly in STEM fields (Belanger et al., 2020; Brown et al., 2015; Clark et al., p. 251 2016). Although this is ↳ not the way J. J. Gibson (1979) originally intended to use the term affordances, thinking in terms of possibilities for action, be they physical or through artificial constraints of job responsibilities, can be valuable for understanding how people think and act in their environments.

Perceiving the Movements of Others

At the intersection of perception and social cognition is the perception of the movements of others. The perceptual system is highly tuned to perceive others' biological movements. People can recognize their friends, even from far distances, from their walking movements. Companies now hire people to stand on street corners spinning signs because the biological motion attracts attention so easily.

Apparent Biological Motion

A remarkable finding regarding biological motion is that the perceiver's own biomechanical limitations constrain their perception. This is demonstrated by contrasting what happens with nonbiological motion. The visual system perceives motion by detecting patterns of stimulation that frequently coincide with moving objects. For example, imagine a ball traveling from left to right. As the ball's position shifts, it will cause different photoreceptors in the eye to fire. The sequence of these firings will lead to neurons in the region of the brain that responds to motion (area MT) to fire, thus giving rise to the perception of motion. However, it is possible to reproduce these patterns without any motion if, instead of a ball moving, we were to shine a light at one location, turn it off, and then shine another light at the next location, and so on. This, too, would cause a sequence of firing that would lead to the perception of motion, albeit illusory motion. Indeed, this is the mechanism by which people see motion in movies, scrolling billboards, and flipbooks. There is no motion, yet the visual system perceives movement. This phenomenon is called apparent motion. The rule for apparent motion is to perceive the shortest, straightest path. If a light flashes at one location, then another light flashes at a second location, and this process repeats, the perceiver will see the object move back and forth in a straight line. There are many ways an object could move between the two locations, such as in a circular path, but the visual system will only see one route: straight.

However, with apparent motion of the human body, the rules take into account what the body can and cannot do (Shiffrar & Freyd, 1990). Participants were shown two images, presented repeatedly in alternating order, of a body in different positions (see Figure 9.4). The body positions were chosen such that moving from one body position to another required a movement that was not straight (such as rotating one's arm downward). Thus, the shortest possible path for the hand to move from one position to the other was not biomechanically possible. For each display, participants were shown two possible paths of motion. Path A was the shortest path but was physically impossible because of joint or solidity constraints (such as a body part not being able to move through another body part). Path B was physically possible. Participants could select A, B, both, or other. Participants selected Path B (the longer biomechanically possible path). That perception of bodily movement is different than for object movement reveals an effect of action on perception: The action repertoire of the body influences perception of biological movement. The visual system is also tuned to the timing required to make biological movements. When the speed of the presentation of the two images was so fast that a person could not physically make the movement, the visual system reverted to the rules for objects and participants selected Path A more frequently than Path B
p. 252 (see also Grosjean et al., 2007). ↳

Figure 9.4 Two images used in the experiment to study the impact of biomechanical constraints on biological apparent motion. Image from Shiffrar and Freyd (1990).

Coding the Kinematics of Observed Actions

Aside from distinguishing between biological and nonbiological motion based on alternating images, are people able to infer the intentions of others based on their movement kinematics? For social cognition, it would be very useful to gain an understanding of other actors' intentions and goals based on their movements. Such an understanding might feed into other mechanisms supporting social cognition. Is there evidence to suggest that action kinematics may be used to recognize others' actions or even "communicate" one's action intentions? Indeed, a body of work indicates that (a) observers are able to infer a range of features of observed actors based on subtle kinematic differences, and (b) actors make slight modifications to their action kinematics in social versus nonsocial settings. We will discuss evidence for these assertions next.

Actor-Specific Inferences Based on Observed Action Kinematics

There is a range of evidence to suggest that people can infer many features of observed actors from subtle differences in action kinematics. Based on simple point-light displays recorded from people walking (Johansson, 1973), people are able to identify at above-chance levels whether the recorded action kinematics correspond to a male or female (Cutting et al., 1978; Kozlowski & Cutting, 1977). Aside from such physical characteristics, people are also able to reliably infer the walker's emotional states (Alaerts et al., 2011; Dittrich et al., 1996).

Interestingly, people's ability to distinguish between social versus nonsocial action intentions based on action observation has also been demonstrated in more hands-on (pun intended) contexts. For example, Sartori and colleagues (2011) recorded movements of people who performed a reaching movement toward a wooden block when the block was either lifted and placed on a target, lifted and used to build a tower with another person (who also transported a block, in a cooperative way), or lifted to place the block into a target area before a competitor did. Participants then viewed the first part of these actions and had to judge aspects of the observed actions. In different conditions, they chose whether the action was either a natural-speed or p. 253 a fast-speed individual movement, a cooperative versus ↳ a natural-speed individual movement, or a competitive versus a fast-speed individual movement. The results showed that people could discriminate between each of these contexts successfully. This is especially remarkable because the participants only saw initial phases of these recorded movements.

Interestingly, the researchers also varied whether the movies displayed arm movements or if the movies included the actor's face. For discriminations that involved distinguishing social (i.e., either cooperative or competitive movements) from nonsocial (i.e., speed of individual actions) actions, performance improved when faces were visible. For discriminations between natural-speed and fast-speed individual movements, participants performed better when they only saw the arm. Thus, multiple cues may be integrated to infer action intentions. Which cues are used may depend on whether the action involves a social context.

How much information do people need from the observed action kinematics to successfully infer intentions in the above-described scenario? To address this question, Manera and colleagues (2011) asked participants to complete the same task as Sartori et al. (2011) and compared performance when the participants saw movies showing the full arm to performance when participants only saw point-light display recordings. Although participants performed better when they had full view of the moving-arm condition, they did perform significantly better than chance based on the point-light displays as well. This was true for each of the comparisons, except for judging natural-speed individual movements versus cooperative movements. In all, the results of these experiments indicate that low-level visual kinematic information provides powerful cues for inferring intentions in other people and that observers are able to use such cues for that purpose. Inferring other people's intentions is of critical importance for social cognitive processes.

The just-described work indicates that observers make inferences based on observed movement kinematics. But do they adjust their own subsequent movements based on such information? A study by Meulenbroek and colleagues (2007) suggests that they may. In their study, two participants sat across a table from each other as they took turns lifting different cylindrical objects. The experimenters cleverly used the assumed relation between the size and weight of an object (i.e., larger objects are assumed to be heavier) to deceive the actors' expectations about object weight. In each trial, the first actor picked up the cylinder and placed it in the middle of the table. The second actor then grasped it and placed it on a target. In some trials, a larger cylinder was purposely made to be relatively lightweight. In cases when the cylinder was relatively large in size but made to be lighter in weight than expected, the first actor lifted the object higher than they would have because of their incorrect prediction of object weight (similar to the experience of lifting an empty carton of orange juice when you expect it to be full). The critical question was whether the second actor would also lift the object higher than expected or if they would use the perceived action information from the first actor to adjust their own subsequent transport action. The results indicated that participants quickly modified their lifting forces based on the observed action. Thus, kinematic information of others can readily be used to adjust one's own action execution.

Modifying Action Kinematics to Communicate Action-Relevant Information

Aside from actors being able to use observed action information to adjust their own actions, do actors also intentionally modify their kinematics to communicate action-relevant information to others? Anecdotally, you may have experienced how coaches amplify specific aspects of their kinematics to emphasize what they are trying to demonstrate in training. For example, a soccer coach may slow down a demonstrated action to exaggerate how placement of the foot on a ball changes depending on whether they are trying to teach how to pass or shoot. In ballet, dancers ↳ exaggerate many aspects of their movements for stylistic purposes and to communicate emotional expressions through their dance.

Beyond anecdotal evidence, are there empirical findings to suggest that actors modify their kinematics to communicate action-relevant information to an action partner? Several studies support this notion. Sacheli and colleagues (2013) asked two participants sitting across from one another with two bottles directly positioned in front of them on a table (one for each participant) to grasp their respective bottles. They had to do so in synchrony while they adopted either a power grip or a precision grip, depending on the condition. Critically, only one of the participants had knowledge about which grip to perform before the start of the action, whereas the other actor had to infer the correct grip based on their partner's action. The participants were not allowed to verbally communicate during the task. The results indicated that the *informed* actor modified their kinematics by changing their wrist height and grip aperture (i.e., the opening of the hand) early in the movement to provide the *uninformed* actor with action-relevant information. In a tapping task, Vesper and Richardson (2014) similarly instructed pairs of participants to simultaneously land on a sequence of spatially arranged targets. Conceptually, this task was similar to two guitar players playing a melody together by plucking a sequence of strings. Critically, one actor (the informed actor) in the pair knew the order of the targets, whereas the uninformed actor had to infer it from the kinematic information of the informed actor. Across different conditions, varying amounts of kinematic information was available to the uninformed actor. The results indicated that informed actors modified their movement height to signal a target location out of a range of possible targets to an uninformed actor. They did so by moving lower for nearby targets and by moving higher for targets that were farther away. The informed actors only did so when the uninformed actor had access to their movement kinematics, suggesting that kinematic modifications served to inform their action partner.

In both above-described studies, intentional modifications to the movement kinematics by an informed actor resulted in successful task performance by both actors. How fine-grained are the modifications to kinematics by an informed actor to communicate intentions? To address this question, McEllin and colleagues (McEllin, Knoblich, & Sebanz, 2018) used a virtual xylophone-playing task in which participants played simple xylophone melodies. They did so either by themselves (alone), for a learner who was watching them play (a demonstration), or together with a partner (joint action). The critical question was whether a player would differentially modify their kinematics across the three scenarios. The reasoning was that if actors change their kinematics just to communicate aspects of their actions to others, then their kinematics for the demonstration and joint action conditions should be similar to each others' but differ from the alone condition. If part of the adjustment in kinematics is also for the purpose of coordination with another actor, then all three conditions should show kinematic differences. The authors showed that, indeed, the joint action condition also differed from the demonstration condition. They did so by showing differences within the joint condition between trials in which the action partner knew the sequence of tones versus trials in which they did not. Altogether, the authors argued that an actor's kinematics may reveal information about the communicative as well as coordinative context in which the action takes place. In a follow-up study, the authors also showed that observers were able to identify the action context based on point-light displays of the virtual xylophone actions (McEllin, Sebanz, & Knoblich, 2018). Again, perception of action kinematics carried a surprising wealth of information relevant for social cognition.

The perception and production of action kinematics may also support coordination and communication
p. 255 more explicitly through gesturing. A substantial body of work (see ↳ Goldin-Meadow, 1999) has shown that gesturing adds nonverbal information that is used for both learning and communication. First, gestures add information for the person expressing the gestures. For example, work by Beilock and Goldin-Meadow (2010) indicated that people were better at problem-solving when they could use gestures in their initial explanations of a Tower of Hanoi task (i.e., a standard problem-solving task) than if they were not allowed to do so. Gestural information has also been shown to support successful communication and to scaffold learning in instructional settings (Cook et al., 2008). In particular, learners may benefit from observing gestures because these gestures provide nonverbal, task-relevant information that may not be expressed through speech. Thus, the perception of action gestures can be used to support communication and learning.

Athletes sometimes exploit others' ability to infer intentions from the perception of action kinematics. An example of this comes from fake outs, in which athletes align their body in ways to suggest that they will move, pass, hit, or shoot in one way or direction and then actually do so in another way or direction. Research on these fake outs (see Güldenpenning et al., 2017, for review) has indicated that people are sensitive to fake outs in at least two different ways; first, people can fall for fake outs, regardless of their level of expertise with the particular sport, and second, those with expert abilities tend to outperform novices in their ability to detect fake outs. With respect to the first point, it has been shown that both experts and novices show detection errors for fake outs and that these detection errors can result in performance decrements. With respect to expertise, experts have consistently been shown to be better at the detection of fake outs compared to novices. They have also been shown to be less affected by fake outs in terms of performance decrements. Fake outs provide an interesting window into the interplay between common codes for perception and action with social cognition at the level of intentions.

Entraining Through the Perception of Others’ Movements

Whereas fake outs reflect higher level social cognitive mechanisms employed to use action kinematics to deceive others about action intentions, the perception of actions also influences one’s own actions through lower level perceptual dynamics. One common phenomenon in this regard is entrainment. Entrainment refers to the observation that two or more moving entities may align the phase relationship of their movements more frequently than would be expected by chance. Just as schools of fish tend to entrain or even synchronize their movements, people tend to entrain when they walk or rock in rocking chairs next to each other as well. For example, Richardson and colleagues (Richardson, Marsh, Isenhower, et al., 2007; see Figure 9.5) showed that people entrain when they rock in rocking chairs across from one another (while being able to see each other) and that they do so even when the natural frequencies of the respective chairs differ. Thus, seeing another person move at a certain frequency tends to influence one’s own movements toward that frequency. With respect to social psychological variables, it has also been shown that the extent to which people synchronize with one another influences how much they report liking the other person (Hove & Risen, 2009; Wiltermuth & Heath, 2009). Entrainment relates to behavioral mimicry (e.g., Chartrand & Lakin, 2013), which can be defined as the automatic imitation of gestures, postures, mannerisms, and other motor movements. Entrainment particularly pertains to above-chance levels of synchronization in the coordination dynamics of two or more continuous signals. Entrainment forms one of the hallmark phenomena that is amenable to dynamical systems approaches. We encourage the reader to p. 256 learn more about these approaches (e.g., Schmidt et al., 2011). ↳

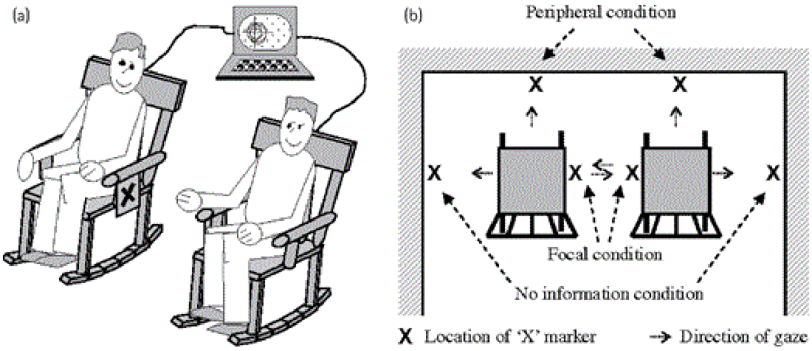

Figure 9.5 Illustrative setup of an entrainment paradigm in which people rocked in rocking chairs while they had different amounts of visual information about the other’s actions. Image from Richardson, Marsh, Isenhower, et al. (2007).

Perceiving in the Context of Other Actors

How do we perceive and represent the world in the context of others, some of whom may serve as action partners? The studies above provide some indications of how actions may be modified to accomplish coordination with others. The sharing of codes between perception and action also supports joint actions in a broader way. Joint actions are actions in which we coordinate our own actions in time and space with those of others to bring about a change in the environment (Sebanz et al., 2006). Joint actions fall at the intersection of cognition and social processes, because they require the integration of individual-level intentions with dyadic or larger group intentions. How are core cognitive processes influenced by other actors, and how do they support action integration between an actor and action partners during joint actions?

One of the first demonstrations of how other actors influence core cognitive processes comes from the discovery of the joint Simon effect (Sebanz et al., 2005). We have long known that compatibility between a stimulus location and a response location influences responding, with faster responses and lower error rates occurring for compatible (e.g., responding with a left button press to a stimulus on the left side of a screen) versus incompatible (e.g., responding with a left button press to a stimulus on the right side) arrangements (Simon, 1969; see Figure 9.6). The joint Simon effect is an interesting extension of this finding because it speaks to the influence of other actors on our own representation of space. While splitting up a standard Simon task between two actors (i.e., one actor responding when the stimulus implied a "left" response and another actor responding when the stimulus implied a "right" response), actors still showed a compatibility effect, even though their individual tasks did not involve a choice between two possible response locations. After all, each actor performed a so-called *go/no-go task* because they each had only one button they either pressed or did not press depending on the stimulus. By demonstrating a joint Simon effect, the results demonstrated that actors co-represent other actors around them and code aspects of other actors' tasks.

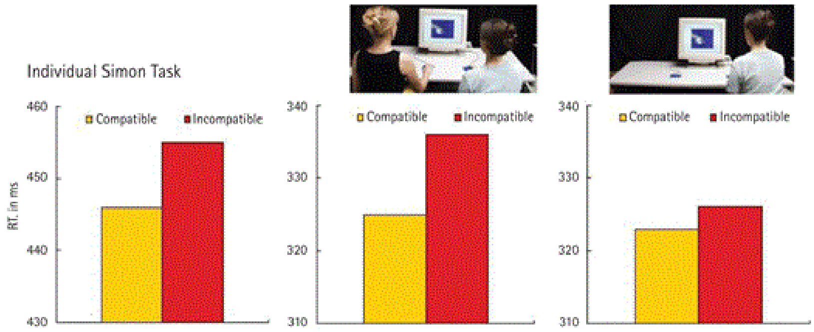

Figure 9.6 The joint Simon task and effect. Participants show a reduced reaction time for incompatible trials when they perform the full task alone or share responses with a coactor, but not when they perform half of the task alone. Image created based on Sebanz et al. (2003).

Different accounts for co-representation have been developed, but they share that they are representational in nature. Here, the term *representational* is intended to indicate that internal codes are used as stand-ins for external states and events. These codes tend to be symbolic and computational in nature and serve the purpose of directing behavior. Importantly, representations can be flexibly activated without needing the
p. 257 immediate ↳ presence of their external referent (e.g., Haugeland, 1991). Representational accounts differ from, for example, dynamical systems accounts that have been developed for processes such as entrainment. Dynamical systems accounts avoid representations by instead accounting for observed behavior based on the dynamically enfolding interactions between an organism and its environment.

The joint Simon effect has been replicated many times, and the influence of many different factors has been examined. These factors range from the importance of lower level factors, such as seeing the other actor or not (e.g., Tsai et al., 2006; Welsh et al., 2007) and attention (Liepelt, 2014), to whether actors have the same or different beliefs about object locations (e.g., van der Wel et al., 2014), to higher level factors such as whether the other actor is perceived to have a sense of agency and intentionality in their actions (see Dolk et al., 2014, for review). The influence of a host of social variables on task co-representation has been studied as well, including the influence of different moods, being in-group versus out-group (e.g., Constantini & Ferri, 2013; McClung et al., 2013, Nafcha et al., 2020), being of the same or a different race (e.g., Müller et al., 2011) or social status (Aquino et al., 2015), and being of the same or opposite gender (Mussi et al., 2015). These studies have generally found that co-representation is stronger when there is greater similarity between the two participants performing the task. Affect has also been shown to influence task co-representation, because participants may co-represent when they are in a positive or neutral mood but not when they are in a negative mood (Kuhbandner et al., 2010). The interaction partner's affect also may play a role in co-representation, as has been shown by differences in co-representation when participants jointly performed a task with a confederate who was friendly and cooperative versus competitive and intimidating

(Hommel et al., 2009). In the former case, participants showed a joint Simon effect, but in the latter case they did not. Finally, the strength of romantic feelings toward a partner may influence the tendency to co-represent others' tasks as well (Quintard et al., 2020). Altogether, these findings provide a powerful example that core cognitive mechanisms may be influenced and possibly shaped by social context, making them of interest to those interested in social cognition.

Although there is much evidence to suggest that similar representations and processes underlie individual and joint task performance, there may be interesting differences as well. For example, aside from p. 258 differences in co-representation between competitive and cooperative ↳ settings, it has also been shown that the extent to which the brain responds to actions made by another person seems to differ depending on whether that person is an interaction partner. In a simple reaching and grasping task, Kourtis and colleagues (2014) placed three people, two confederates and a participant, at a table that had a cylindrical object placed in its center. Unbeknown to the participant, one of the confederates was sometimes an action partner, whereas the other confederate only performed individual actions (the "loner"). A cue indicated one of three possible conditions: either one of the three people picked up the object and placed it back down, the participant picked up the object and handed it to the action partner, or the action partner picked up the object and handed it to the participant. While they performed these tasks, kinematics as well as electroencephalograms were recorded. This allowed the researchers to determine whether activation of motor areas prior to action observation depended on the social relationship between the actor and the observer. Participants showed differences in anticipatory motor activation when they expected an action performed by an interaction partner compared to when they expected an action performed by a loner. Thus, the way in which people perceive and process the actions of others depends on their social relationship to those people in action contexts. Consequently, there is a clear relationship between perception, action, and social cognition.

When do mechanisms for entrainment and task co-representation influence actions? One difficulty in resolving this question is that studies on entrainment and task co-representation use different paradigms. In particular, on the one hand, entrainment studies typically employ some continuous, cyclical movement task, such as when people walk, swing pendula, or rock in rocking chairs. On the other hand, studies on task co-representation typically require a single (i.e., discrete) goal-directed response to some stimulus. This difference in tasks is important, because discrete versus continuous movements are considered different classes of movement (e.g., Hogan & Sternad, 2007; Howard et al., 2011). To determine to what extent evidence for entrainment and task co-representation is specific to the types of actions that are used (either discrete or continuous), van der Wel and Fu (2015) studied both phenomena in a single paradigm. Participants sat next to a confederate while they both moved their right hand back and forth between two targets. In the interesting conditions, the confederate moved over an obstacle while the participant did not do so. The question was whether the participants would move higher in those cases, either from seeing the confederate's movements or from co-representing their task. To distinguish between these two possibilities, participants performed the movement task by making either discrete or continuous movement sequences and while the participants could see the confederate's movements half the time. The results indicated that participants moved higher when the confederate cleared an obstacle than when he did not. Thus, participants were influenced by their action partner's task. For continuous movements, this effect depended on the availability of visual information, as would be expected on the basis of entrainment. In contrast, the co-actor's task modulated the height of discrete movements, regardless of the availability of visual information. This study indicates that it is important to consider the kinds of movement tasks within a particular paradigm to ensure that differences in theoretical interpretation are not at least partially explained by differences in motor control.

Mechanisms for Perception–Action Coupling

So far, we have mostly discussed behavioral findings that speak to the notion that perception and action are deeply intertwined. We next discuss how perception and action relate on a mechanistic level.

Common Coding

One prominent theory about how perception and action are related is the theory of common coding (Prinz, 1997). According to this theory, there are underlying representations, or *codes*, that are shared between perception and action. The notion of common coding argues that both perception and action rely on these common representational codes (Prinz, 1997). These codes are somewhat detached from the physical actions themselves, but rather reside at the level of the sensory effects the actions produce. In other words, actions and action goals are coded in terms of the sensory changes they bring about in the environment. Actions are planned based on the perceptual effects the action would produce. So, if one plans to hand someone else a pair of scissors, the idea would be that the codes underlying the perceptual and kinesthetic sensory information related to the action would be represented. These codes then drive the selection and execution of the goal-directed action of handing someone the scissors. Interestingly, because perception and action share these common codes, the person who receives the scissors will also partially activate these same codes, as they observe the action as it unfolds. This approach to action representation is embraced by several theoretical frameworks, such as the theory of event coding (Hommel, 2009) and predictive coding accounts (e.g., Friston, 2009).

Some early data nicely demonstrated how perceiving actions may activate common codes for perception and action (Stürmer et al., 2000). Much work has been conducted since, but this study effectively shows the core notion that seeing action activates common codes. In Stürmer et al.'s study, participants responded to a task-relevant color stimulus on a computer screen by either clinching their hand with a power grip (as if they held a tennis racket) or opening their hand (as if they were waving). Participants made the response in reaction to the color displayed on the screen. Importantly, during this task, participants also saw a hand on the background of the computer screen that either displayed the same hand posture (a *congruent* trial) or the "opposite" hand posture (an *incongruent* trial). Although the displayed hand was irrelevant for the color-categorization task, participants were faster on the congruent than on the incongruent trials. This result was taken to indicate that simply observing a hand posture activated the same codes used to adopt the posture, thus providing evidence for common coding. Why would seeing a hand, which was irrelevant for the task posed to participants, impact the speed by which they could form their own hand gesture? The idea is that seeing the hand automatically activated the same codes necessary to initiate their own actions, so when the posture of the depicted hand was incongruent with the postured required by the color, this conflict caused a delay in responses.

Mirror Neurons

Since the mid-1990s, a wealth of evidence has shown that perception and action link to one another at a neural level. The most direct demonstration of this linkage is the discovery of mirror neurons (Rizzolatti et al., 1996). These neurons were first discovered "accidentally," as the researchers were trying to understand when particular neurons in the ventral premotor cortex of a macaque monkey would fire when the monkey reached for food. To their surprise, they found that some neurons fired both when the monkey moved its hand and when the monkey observed a grasping movement (see Figure 9.7). This observation was significant because, at the time, perception and action were considered to largely take place in different parts of the brain, and certainly in different cells. Mirror neurons revealed that the same neurons could code both for the action and for the perception of the action.

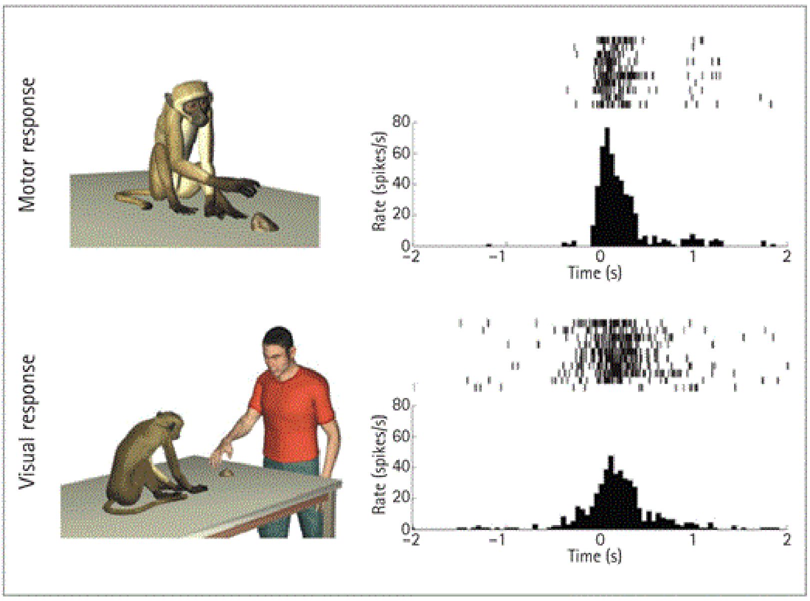

Figure 9.7 Mirror neurons in a macaque monkey fire when the monkey reaches for an object, as well as when the monkey observes a human reach for an object. Image from Casile et al. (2011).

The discovery of mirror neurons gave rise to claims about their involvement in a wealth of processes, with
p. 260 some going as far as to argue for their involvement in smoking behavior (Pineda ↳ & Oberman, 2006). Although it is important to be careful about attributing a wide range of social, emotional, cultural, and developmental processes to mirror neurons (see Gallese et al., 2011), their role in action perception is well supported based on single-cell studies in monkeys as well as humans (Mukamel et al., 2010). Direct evidence for mirror neurons is only possible based on single-cell recordings, but there is also a substantial body of neuroimaging studies that is consistent with mirror system activation. For example, studies have shown that action expertise influences the brain's response to observed movements, almost as if a person with matching motor expertise is moving during the observation of actions. In one such study, Calvo-Merino and colleagues (2006) showed movies of ballet and capoeira to participants as they lay in a magnetic resonance imaging scanner. By using participants who were novices, experts in ballet, or experts in capoeira, these researchers showed increased activation in motor areas when participants watched the actions they could perform as experts relative to those who did not have expertise in. In a study with a similar logic, Aglioti and colleagues (2008) showed that expert basketball players were better than novices and expert watchers (i.e., sports commentators) at predicting the outcome of basketball shots from movies that were cut short before the ball left the shooter's hand. At a muscular level, these authors additionally showed that, relative to novices and expert watchers, players showed increased activation in the set of muscles related to basketball shooting movements, but not in other muscles. These and similar results (see van der Wel et al., 2013, for a review) demonstrate that what our bodies can do influences the way in which we perceive and resonate with actions of others around us.

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Action-Specific Perception

Much of the focus of the chapter thus far has been on the role of action when perceiving others. Action's influence on perception extends beyond the perception of action. Indeed, action-related processes impact the perceptual experience of even low-level features such as spatial perception. According to the action-specific account of perception, perceivers see the spatial layout of the environment in relation to their ability to act in it (Proffitt, 2006; Witt, 2011). For example, softball players who are hitting better than others judge the ball as bigger (Gray, 2013; Witt & Proffitt, 2005). As another example, hills look steeper to observers who are fatigued, less fit, or older (Bhalla & Proffitt, 1999). The idea is that if the target is easier to obtain, perception of the target's spatial properties is impacted. Hills that are easier to climb because the person has more energetic resources appear less steep than when the person has fewer energetic resources.

Action-specific effects have been found in a wide variety of scenarios. They have been found in athletes including softball players, tennis players, golfers, swimmers, archers, and those skilled at parkour (Y. Lee et al., 2012; Taylor et al., 2011; Witt et al., 2011; Witt & Sugovic, 2010). While these are fun demonstrations, they can create a false impression that these effects are specific to athletes. They are not. Rather, action-specific effects occur in a wide range of settings. Following Witt and Sugovic (2013b), we organize action-specific influences into four categories of additive effects. These are the anticipated success of an action, the energetic costs associated with performing the action, the benefits associated with successful action, and the penalties associated with failure.

Action-Specific Effects Related to Anticipated Success

One category of action-specific effects relates to anticipated success at performing an action. Examples include the previously discussed relationship between athletic success and perceived target size. It should be noted that the direction of these effects depends on the relationship between anticipated success and the specific object being perceived. Targets are judged as bigger to archers who are shooting better than others, and bigger targets would be easier to hit (Y. Lee et al., 2012). In contrast, the net in tennis is an obstacle, so players who are returning the ball better than others judged the net as lower or smaller (Witt & Sugovic, 2010). Similarly, a wall is judged as shorter to traceurs (i.e., experts in parkour) compared with novices (Taylor et al., 2011).

Anticipated success also relates to the physical capabilities of the body. For example, objects that are just beyond arm's reach appear closer when the perceiver uses a tool to reach to the objects (Costello et al., 2015; Davoli et al., 2012; Osiurak et al., 2012; Witt et al., 2005). A similar pattern emerges when virtual reality is used to make the arm appear longer (Linkenauger et al., 2015; Yang et al., 2020). In addition, objects that can be grasped more easily are judged as smaller (Linkenauger et al., 2010, 2011).

One action-specific effect related to anticipated success is the Pong effect. The Pong effect is the difference in perceived speed of a ball depending on the anticipated success with which the ball can be blocked. The task is modeled after the classic computer game *Pong*. A ball travels across the screen at one of six speeds, and the participant attempts to block the ball by using a joystick to control the position of a paddle on the screen (see Figure 9.8). The task of blocking the ball is made easy by rendering the paddle to be big or difficult by rendering the paddle to be small. After each attempt to block the ball, participants estimate the speed of the ball. Many studies have shown that the ball is judged to be moving more slowly when the participant played with the big paddle than when they played with the small paddle (Witt & p. 262 ↳ Sugovic, 2010, 2012, 2013a). This difference in estimated ball speed between the small and big paddles is called the Pong effect.

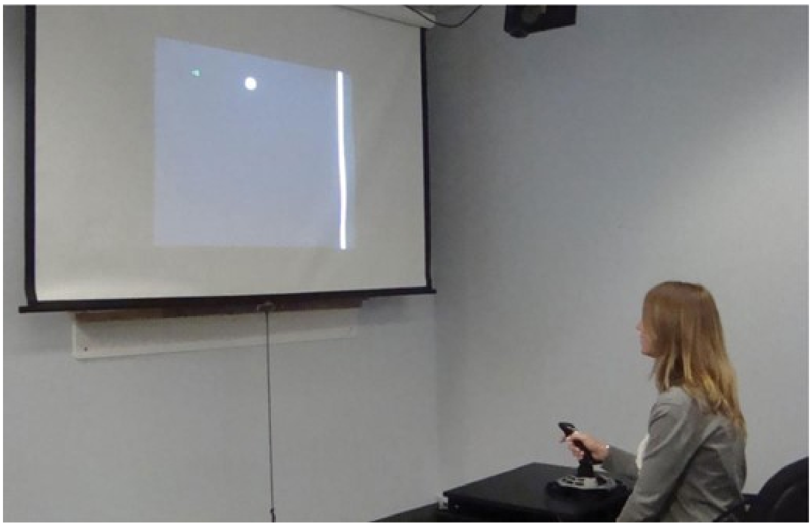

Figure 9.8 Mila Sugovic demonstrating the Pong task. The paddle is difficult to see in the image but was easy to see when doing the task. In the original Pong studies, the task was projected on a large projection screen, as shown here. In later Pong studies, the task was performed on a desktop computer.

A critical question is whether a person's ability to act genuinely influences perception. Alternative explanations are that perception is unaffected and the effects are caused by an influence on the responses instead (Durgin et al., 2009; Firestone & Scholl, 2016; Woods et al., 2009). These alternative explanations include response bias and judgment-based processes. For example, participants might infer the purpose of the experiment and alter their responses to be compliant (Wesp & Gasper, 2012). As another example, participants might feel that the task is harder and alter their judgment to accommodate how hard it feels (Woods et al., 2009).

There are many reasons why it is important to differentiate between perceptual effects and judgment-based effects. One reason is theoretical: If action-specific effects are truly perceptual, this has implications for theories of vision, which would need to be altered to accommodate action's influence on spatial vision. Another reason speaks to the nature of these effects. Perceptual effects tend to be cognitively impenetrable. This means that what a perceiver knows does not alter what they see. Take the classic visual illusion of the Shepard tables. The two tabletops appear to differ in shape. However, their shapes are the same. Knowing this information does not change how they appear. The illusion persists despite knowledge that it is an illusion. If action-specific effects are also perceptual, knowing that one's body and potential for action alters spatial perception will not lessen its effects on perception.

There have been many investigations as to whether action-specific effects are truly perceptual. Some of these experiments have successfully ruled out a perceptual explanation. For example, it seems unlikely that dart-throwing performance in novices relates to perceived target size and instead relates to judgments p. 263 (Wesp & Gasper, 2012). With respect to throwing a ↳ ball rather than a dart at a small target, research suggests that action influences memory rather than perception (Blaesi & Bridgeman, 2015; Cooper et al., 2012). However, other action-specific effects are not so easily explained by nonperceptual accounts (Molto et al., 2020; Witt, 2017).

The literature on the Pong effect and the experiments to differentiate perceptual from nonperceptual effects is too numerous to detail here. Detailed reviews of this work can be found elsewhere (Witt, 2017; Witt et al., 2016), but we instead focus on two sets of studies from our own research that indicate that these effects are not merely the product of response biases but instead were perceptual in nature. One set of experiments tested the link between knowledge or inference of the Pong effect and the magnitude of the effect (Witt et al., 2018). When participants were queried at the end of the experiment about their assumptions of the purpose of the experiment, approximately half indicated that they suspected the purpose was to determine whether paddle size would impact perceived speed. However, the magnitude of the Pong effect was similar regardless of whether they suspected the correct purpose. Had response bias driven the effect, only participants who correctly inferred the study's purpose should have shown the Pong effect. In another experiment, participants were explicitly told the purpose of the study at the beginning and were told to report how the ball appeared to move without being biased by extraneous factors. Even with these instructions, participants still showed the Pong effect, and to a similar magnitude as in previous studies. Just like knowledge of the Shepard tables does not lessen the illusion, knowledge of the Pong effect did not eliminate or even lessen the magnitude of the Pong effect.

Another technique to investigate the perceptual nature of the Pong effect is to measure implicit, action-based responses. In a modified version of the task, a fish moved across the screen and participants pressed a button to shoot a net up to try to intersect the fish. As in the Pong task, participants judged the fish to be moving faster when the net was small compared to when the net was big. Importantly, we also examined the timing of when participants shot the net. If the fish truly appeared slower when the net was big, participants should wait longer to shoot it compared with the smaller net. Indeed, this is what they did (Witt & Sugovic, 2013c). Furthermore, this action-based measure revealed the same pattern even when no explicit speed judgments were made (Witt, 2018). Participants' actions showed that their anticipated success at blocking the fish influenced the perceived speed of the fish.

Action-Specific Effects Related to Energetic Resources

Even when an action can be successfully completed, there can be energetic costs associated with performing the action. The body has limited energetic resources and must conserve energy to avoid exhaustion. These energetic costs are particularly relevant for spatial perception (Proffitt, 2006). The energetic costs associated with ascending a hill affect perceived slant of the hill and perceived distance on the hill (Bhalla & Proffitt, 1999; Laitin et al., 2019; Proffitt & Zadra, 2011; Schnall et al., 2010; Stefanucci et al., 2005; Taylor-Covill & Eves, 2014, 2016; Tenhundfeld & Witt, 2017).

Anticipated energetic costs also affect perception. Visuomotor recalibration, as occurs when walking on a treadmill (Rieser et al., 1995), can make people anticipate having to exert more energy to walk a prescribed distance. When walking on a treadmill, the visual input does not change in the way it would during walking on the ground. Specifically, walking on a treadmill leads to zero optic flow. Optic flow refers to the patterns of velocities and directions of movement in the light reflecting into the eye (J. J. Gibson, 1966, 1979). When a person walks, their movement through space causes corresponding optic flow, in this case, expansion

patterns. But when on a treadmill, the forward walking is paired not with expanding optic ↳ flow, but rather with stationary optic flow. Thus, walking on a treadmill leads to a recalibration that forward walking leads to zero optic flow. In other words, people anticipate that they will need to expend quite a bit of energy just to stay in place! After calibrating people to this new relationship between walking and optic flow, participants judged distances to be farther away (Proffitt et al., 2003; White et al., 2013; Witt et al., 2004, 2010).

One of the first studies that initiated the action-specific account of perception found that participants who wore a heavy backpack judged hills to be steeper compared with participants who did not wear the backpack (Bhalla & Proffitt, 1999). In addition, participants who wore a heavy backpack judged distances as farther compared with participants who did not wear the heavy backpack (Proffitt et al., 2003). These backpack effects have not been particularly robust, with several replication failures (e.g., Hutchison & Loomis, 2006; Woods et al., 2009). The current state of the field is to acknowledge that under the tested circumstances, backpack wearing likely does not impact slant perception. This does not mean that wearing a backpack could never influence slant perception, but rather that the current scenarios used to test this effect have not been suitable to prove its existence (Philbeck & Witt, 2015).

A recent meta-analysis on energetic effects on distance perception has provided strong support that energetic costs can affect perceived distance (Molto et al., 2020). The meta-analysis included data from 37 studies with 1,035 total participants and found an effect size of Hedge's $g = 0.29$, corresponding to a small effect. Moreover, the data from the studies failed to provide evidence for nonperceptual accounts of these action-specific effects.

Action-Specific Perception and Social Cognition

What are the implications of action's effect on perception for social cognition? In general, if a factor affects cognition, it is likely to also have implications for social cognition. The action-specific account shows that a person's ability to act influences spatial cognition. Here, we also review evidence for its impact on social cognition. In particular, we review evidence for the two other categories of action-specific effects: the benefits of successful action and the costs associated with failed action.

Just as a person's ability to act can influence spatial perception, so, too, can the consequences of failure and the fear associated with these consequences. One example is the impact of spiders on spatial perception. Spiders appear bigger to people who are more phobic of spiders (Vasey et al., 2012). Spiders appear closer than a neutral object, particularly to those with depleted psychosocial resources who are thus less able to cope with the threat, and particularly to those who rated the spider as more threatening (Cole et al., 2013; Harber et al., 2011). Spiders also appear to move faster compared to neutral objects. Participants attempted to block spiders or a ball with various sized paddles in an extension of the Pong effect. The bias to estimate the spiders as moving faster was independent of the ease with which they could be blocked. The combination of the two main effects and no interaction between the object to be blocked and paddle size suggests independent, additive effects of threat and one's ability to act (Witt & Sugovic, 2013b).

Fear influences spatial perception in other contexts of action as well. A threatening person appears closer (Cole et al., 2013). For novices, standing on a skateboard at the top of a hill makes the hill appear steeper (Stefanucci et al., 2008). Simply standing on a balcony makes heights appear taller (Stefanucci & Proffitt, 2009; Stefanucci & Storbeck, 2009).

Other emotional states also burden the perceiver and impact spatial perception. One such example is the burden of secrets. Participants who harbored an important secret judged hills as steeper and distances as farther (Slepian et al., 2012). Another such example relates to sad mood: Participants who were sad judged
p. 265 hills as steeper compared with participants who were ↳ happy (Riener et al., 2011). Feeling misunderstood made hills appear steeper and distances appear farther (Oishi et al., 2013). Feeling powerless made weights feel heavier (E. H. Lee & Schnall, 2014).

Positive emotions also impact spatial perception. Desirable objects such as chocolate and money appear closer (Balcetis & Dunning, 2010). For example, in one experiment, participants estimated perceived distance to a bottle of water. Some of the participants had just eaten salty pretzels and were thus thirstier compared with participants who had not eaten the pretzels. The pretzel group rated the bottle of water as more appealing and, critically, also rated it as closer compared with the nonpretzel group. Other appealing objects such as chocolate and gift cards with money credited to them also looked closer. The judgments of distance included direct measures as well as action-based measures such as throwing a beanbag. Another set of studies showed that the presence of a close friend makes hills appear less steep (Schnall et al., 2008). The idea is that the friend provides psychosocial resources to help offset the physical burden of carrying a heavy backpack up a hill and thus makes the hill appear shallower.

As discussed with the backpack study, we should note replications and failed replication attempts. The studies on perception of spiders have had both exact replications and conceptual replications. Studies on perceived height while on balconies have also had exact replications and conceptual replications, and these studies also used both direct and indirect measures of perceived height. These replications and alternative measures give confidence in these findings. In contrast, controversy surrounds some of these findings, such as the effect of social support on perceived slant (Eves, 2015; Shaffer et al., 2013). But most of the experiments have not been directly replicated in follow-up research. It should be noted that while this could be a fruitful avenue for future research, large sample sizes should be used to provide a more precise measure of the magnitude of any effect. Using the published effect sizes for a power analysis is likely to lead to underpowered research and a failure to replicate that cannot be interpreted because it would be just as likely a result of low sample size as a genuine lack of effect.

A "posterchild" for the replication crisis is the impact of how a person holds their body on hormones and feelings of power. One of the originally reported findings—that holding a power pose can lead to hormonal changes such as an increase testosterone and a decrease in cortisol (Carney et al., 2010)—has failed to be supported (Simmons & Simonsohn, 2017). However, there is strong evidence that the act of positioning and holding one's body in a power pose can increase feelings of being powerful as well as feelings and emotions on a variety of measures (Cuddy et al., 2018). Thus, power posing is one way in which action can affect social cognition.

Gun Effect

We will end this chapter with a powerful and (unfortunately) timely example of the way the cyclical relationship between perception and action impacts social cognition in real-world settings. The example concerns the finding that a perceiver's own ability to act influences perception of whether another person is wielding a gun or a neutral item. In the experiment, participants viewed pictures of a person who was holding either a gun or a neutral object such as a shoe. The task for the participant was to determine whether the held object was a gun or a neutral object. Studies such as these, known as first-person shooter tasks, have revealed numerous biases such as the bias to respond faster when the image depicts a Black person holding a gun than when the image depicts a White person holding a gun (Correll et al., 2002). Another bias occurs when the participant is also holding a gun: Wielding a gun affects perceptual judgments of whether another person is holding a gun compared with when the participant wields a neutral object (Witt & Brockmole, 2012).

p. 266 We will refer to the impact of wielding a gun on perceptual judgments as the gun effect. The gun effect reveals that the perceiver's own abilities to act influence perception of others and the judgments that are made on how to react to other people. The gun effect depends on wielding the gun; simply having a gun visible but with no intention to use it did not lead to a bias in perceptual judgments (Witt & Brockmole, 2012). Thus, the gun effect seems to be specific to acting with the object and is thus specific to the relationship between perception and action.

As with many embodiment effects, there is concern regarding the replicability of the gun-embodiment effect. In the prior research (Witt & Brockmole, 2012), the sample sizes were small. For example, to achieve 80% power to detect the magnitude of effect detected in Experiment 2, one would need a sample size of 61 participants, and the experiment only had 38 participants. Another concern with the prior research is that the obtained p values, which were .02, .03, .10, and .01, fail to provide strong statistical evidence for a genuine effect. To address these issues, the gun-embodiment effect was replicated with a larger sample size of 212 participants (Witt et al., 2020). The evidence provides strong support for the gun effect with the following modifications from the original claims. The effect revealed itself in reaction time and in accuracy rather than in the signal detection theory measure of bias. In addition, the magnitude of the effect was small in terms of standardized effect sizes (d_z = .26 for reaction time and d_z = .26 for accuracy).

This small effect can still be consequential and thus have real-world implications (Funder & Ozer, 2019; Rosenthal & Rubin, 1982). Consider a gun effect of *d* = .25 that affects judgments in a police department of 100 armed officers and compare it to a police department with 100 armed officers who do not experience the gun effect. Assume each officer interacts with 1 unarmed citizen each day for 100 days. This equates to 10,000 interactions for each police department. Also assume that the rate of shooting an unarmed citizen in the case of no bias is .01%. For the unbiased police department, this means that in those 10,000 interactions, 1 unarmed citizen will be shot. What happens in the biased police department given an effect size of *d* = .25? This size bias means that 300 unarmed citizens will be incorrectly identified as being armed. If 1% of armed citizens are shot (or 1% of seemingly armed citizens are shot), that means the biased department will shoot 3 additional unarmed citizens every 100 days simply because of the impact of wielding a gun on perceptual judgments.

Conclusion

Perception and action are deeply intertwined. From birth, the perceptual and action systems coordinate with each other to develop meaningful perception. The constraints of action on perception can be seen with respect to perceiving the actions of others as well as perceiving spatial layout and object identification. Some of the connections between perception and action are intuitive. One must be able to perceive an object to intentionally act on it. Other connections are less intuitive, such as the role of wielding a gun on the perception of others holding guns. We have reviewed several ways that perception and action interact. Many aspects of perception are influenced by action, including the perception of affordances, the perception of actions by other people, the perception of intentions of others, the perception of space, and the perception of objects. The specific mechanisms underlying these various relationships, and the extent to which the mechanisms are common across perceptual domains versus specific to each, are matters for future research. Much of the research on perception and action has been focused on demonstrating a link between the two. Now that these demonstrations are plentiful, the next step for the field is to focus on the mechanisms.

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