

<cn>Chapter 17

<ct>Motor Learning Through Observation

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<txni>Motor skill acquisition typically involves the transfer of information between instructor and learner. A common method of transfer is demonstration. *Observational learning* is the term for the process by which observers watch the behavior of a model and adapt their movement as a result, typically as assessed in a delayed retention test (see Hodges, Williams, Hayes, & Breslin, 2007; Horn & Williams, 2004; McCullagh & Weiss, 2001; Newell, Morris, & Scully, 1985; Vogt & Thomaschke, 2007; Williams, Davids, & Williams, 1999, for reviews). Relevant to this review is the difference between observational learning and observational practice (Vogt & Thomaschke, 2007). Observational learning relates to a situation where a demonstration and physical practice are interleaved (i.e., observe, practice, observe). Observational practice relates to a situation that merely requires the learner to observe and does not involve physical practice.

<tx>It has long been thought that observational learning is a more efficient method of learning than verbal instructions (McCullagh & Weiss, 2001). It is considered a powerful means to transmit patterns of behavior to a learner (Bandura, 1986). The results of a meta-analysis of the literature on observational learning reflected a significant advantage of modeling over practice-only (i.e., discovery) conditions (Ashford, Bennett, & Davids, 2006). Compared with discovery learning, observational learning has been shown to provide both immediate performance benefits and long-term learning benefits in a range of behavioral measures. These include improvements

in movement form and outcome, recall and recognition, decision making, and self-confidence, as well as reduced fear and anxiety (see Hodges et al., 2007, and McCullagh & Weiss, 2001, for more detailed reviews). Although it is clear that observational learning can be an effective teaching tool, understanding the mechanisms underlying this process provides valuable information to optimize the use of demonstrations.

This chapter summarizes the theories, methods, and techniques that have influenced research in the field of adult observational learning. We hope this information will help researchers determine the information and processes guiding this perceptual–motor learning process. We start with some definitions followed by a review of the theoretical approaches that have guided research into observational learning, practice, and imitation. This includes an examination of traditional behaviorally based theories as well as current behavioral approaches and theories that have been guided by neurophysiology and brain imaging research. In the remaining sections we look at measures and manipulations that have been used to explore variables related to the observational learning process. The effectiveness of observation for learning appears to depend on a complex interaction among the observer, model, and task, and thus these characteristics are discussed in relation to the various methods that have been used to assess model effectiveness (e.g., movement kinematics, eye movement recording, brain imaging, point-light models).

Cognitive Mediated Learning

<txni>An initial theoretical explanation for how information is transferred to the observer through modeling was offered by Bandura (1971) in his social learning theory, later revised to

social cognitive theory (1986). Building upon Sheffield's (1961) concept that behavior is stored in symbolic form, Bandura proposed that a representation serves as the mediator between observation and action. Therefore, the quality of the symbolic representation (i.e., the learner's internal standard) was believed to be critical for modeling effectiveness (see Carroll & Bandura, 1982, 1990). Although this theoretical approach has led to numerous experiments exploring task, model, and observer characteristics that maximize learning, it has generally failed to prompt researchers to examine what information is perceived and how it guides subsequent actions. Moreover, the underspecification of the nature of the cognitive representation has afforded researchers few testable hypotheses (Heyes, 2002). Bandura's theory is also primarily based on social learning principles rather than motor learning, and it is possible that the mechanisms for these two functions are quite different (see Horn, Williams, & Scott, 2002).

<tx>In Bandura's formulation, the cognitive representation that guides imitation is acquired before the observer attempts to perform the skill. This was originally termed *no-trial learning* (Bandura, 1965). More recent discussions of when observational learning takes place in the perception–action process have resulted in the terms *late* and *early mediation* (Vogt, 2002; Vogt & Thomaschke, 2007). In late mediation, the motor representation (and hence the motor system) is only formed (or engaged) during movement reproduction and physical practice. In early mediation, the motor system is believed to be involved during observation and no physical practice or translation is needed for motor learning to occur. Although superficially it is tempting to equate Bandura's no-trial learning with early mediation, Bandura did not discuss the involvement of the motor system during observation and argued that the observed information was translated through cognitive processes (see also Heyes, 2002). In view of these latter factors,

and that the motor demands in Bandura and colleagues' tasks were low, we equate his ideas more with late-mediation accounts of observational learning.

The positive effects of observation in the absence of physical practice do not necessarily imply that the motor system is engaged during observation. Considerable evidence suggests that demonstrations help to convey an explicit, cognitive strategy that could result in immediate performance improvements. For example, throwing a dart with an unusual underarm throw to hit a target on the floor (Al-Abood, Davids, & Bennett, 2001), moving a ball quickly to attain a target in the shoot-the-moon task (Martens, Burwitz, & Zuckerman, 1976), and learning to anticipate the trajectory of a stimulus (Kohl & Shea, 1992) are strategies which can be picked up through observation. It is likely that many motor skills have similar explicit strategies that can be acquired merely by observational practice (sometimes to the performer's detriment; see Hodges & Franks, 2002b).

The degree of verbalizable knowledge about the strategy used during performance might indicate the degree of motor involvement during observation, with less-verbalizable knowledge indicative of early mediation. For example, Mattar and Gribble (2005) provided an example of early mediation during observational practice. Observers acquired a novel motor action that required dynamic adaptations to motor perturbations even though they performed an attention-distracting arithmetic task during observation. Because the participants still learned the action, the authors argued that learning occurred at an unconscious level through the utilization of the motor system. Furthermore, a second group of participants who performed a nonrelated motor action during observation showed compromised performance. The authors concluded that the motor system

was involved at the observation stage and that a cognitive strategy was not responsible for learning. Similarly, Heyes and Foster (2002) found that the degree of positive transfer in a keyboard sequence task depended on the effector. This finding would suggest some priming of the effector during observation and hence supports early mediation views of learning (see also Porro, Facchin, Fusi, Dri, & Fadiga, 2007).

We hypothesize that in motor tasks where the rule or strategy governing performance is difficult to ascertain, the motor system is likely to be more engaged during observation, a finding that is somewhat supported by neurophysiological evidence, as discussed later (Buccino et al., 2004). Indeed, there is evidence from sequence learning tasks that explicit instructions concerning the regularity of the sequence can interfere with performance and perhaps change the mode of control (and hence involvement of the motor system) in a similar manner to the strategies discussed here (see Berry & Broadbent, 1988; Green & Flowers, 1991; Magill & Clark, 1997).

A number of authors have extended Bandura and colleagues' early work (e.g., Carroll & Bandura, 1990) showing that cognitive processes such as detection and correction of error are aided by demonstrations, supporting the idea that a cognitive representation for the motor skill is acquired through observation. For example, observational practice was as effective as physical practice when error recognition was assessed during a serial key-press task (Black & Wright, 2000; Black, Wright, Magnuson, & Brueckner, 2005). Although Shea, Wright, Wulf, and Whitacre (2000) found advantages during retention for a physical practice group versus an observation-only group, both groups performed similarly on a transfer task where adaptability of the acquired cognitive strategy was required. Factors such as practice schedule (Wright, Li, &

Coady, 1997; however, see Lee & White, 1990) and augmented feedback (Badets, Blandin, Wright, & Shea, 2006), which have been shown to influence physical practice, have also been shown to affect the observation process. Because these effects are believed to be mediated by processes related to recall, effort, and elaboration, it is argued that demonstrations engage the observer in cognitive and neurological processes similar to those adopted during physical practice (Badets & Blandin, 2004, 2005; Blandin & Proteau, 2000; Meegan, Aslin, & Jacobs, 2000).

In summary, there is significant evidence that observational practice and learning typically engage the cognitive system of the observer and that this higher-level processing of the perceptual information might facilitate transfer to new yet similar task situations (e.g., Shea et al., 2000). Observational practice is rarely equal to physical practice, and as suggested by a number of authors, motor practice appears necessary to calibrate the motor system (Shea et al., 2000) and aid in the development of a motor representation of the action (Vogt & Thomaschke, 2007).

Visuomotor Coupling and Direct Learning

One of the mechanisms that has been proposed to mediate observational practice and learning is mental imagery. Jeannerod (1994) proposed that observational practice involves neural mechanisms similar to those involved in mental imagery, with the only difference being the presence or absence of an external stimulus (for reviews, see also Annett, 1996; Jeannerod, 2001; Jeannerod & Frak, 1999; Vogt, 1996). For example, first-person actions (as would be self-generated in imagery) and third-person actions (as would be observed in demonstrations) share

similar neural pathways (e.g., Anquetil & Jeannerod, 2007). Motor imagery also results in increased activity in cortical motor areas, suggesting that covert action simulation as a result of imagery or observation engages processes similar to those engaged by the actual action (e.g., Decety, Sjoholm, Ryding, Stenberg, & Ingvar, 1990; Grafton, Arbib, Fadiga, & Rizzolatti, 1996; Tomasino, Werner, Weiss, & Fink, 2007). People have also shown difficulty imaging actions they cannot perform, a phenomenon again suggesting the commonality of the observation for action and imagery processes (see Mulder, Zijlstra, Zijlstra, & Hochstenbach, 2007).

Despite evidence showing the similarity of these processes, Ram, Riggs, Skaling, Landers, and McCullagh (2007) found that observational learning was better for acquiring form and outcome in weightlifting and balance tasks compared with imagery conditions. In these experiments, participants were not able to form an accurate image of the action in the absence of demonstrations, thus hindering any covert action simulation and development of an appropriate cognitive representation. From a theoretical perspective, imagery might be involved in both early and late mediation, facilitating covert action simulation during observation and movement recall and reproduction processes during physical practice, respectively.

Studies on imitation in newborns showed that facial and hand gestures performed by adults could elicit similar actions in the newborn (Meltzoff & Moore, 1977). The active intermodal matching (AIM) theory resulted from this work and similar studies, which proposed an innate supramodal system in infants that had a common pathway for observation and execution of motor acts (Meltzoff & Moore, 1997). Similar theories have been proposed for adults, including common-coding theory (Prinz, 1997), whereby perceived events and planned

actions share a common representational domain, and direct matching, where it is proposed that perception automatically activates the observed response (Meltzoff, 1993; Meltzoff & Moore, 1983, 1989, 2002). Several lines of evidence support these viewpoints. These are reviewed below in reference to neurophysiological data and then behavioral measures.

The discovery of similar patterns of cortical activation during both observation and physical production of a movement provides the best support for the capability of direct matching between action and perception (see Brass & Heyes, 2005; Rizzolatti, Fogassi, & Gallese, 2001; Rumiati & Bekkering, 2003; Vogt & Thomaschke, 2007; Wilson & Knoblich, 2005). As a result of advances in methodologies for measuring brain activity, a neurophysiological network that is involved in imitation, the mirror neuron system (MNS), has been discovered (see Rizzolatti & Craighero, 2004, for review). Mirror neurons were first discovered in the macaque monkey in area F5 of the premotor cortex and in the rostral section of the inferior parietal lobule, and strong evidence has been provided that similar structures are present in humans (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Fogassi et al., 2005; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). The most common explanation of why these areas are activated during observation is that observation automatically evokes a motor representation of the action, forming the basis of action imitation, understanding, and anticipation (for reviews, see Elsner & Hommel, 2001; Fadiga & Craighero, 2003, 2004; Iacoboni, 2005; Prinz, 2006; Rizzolatti & Craighero, 2004; Rizzolatti et al., 2001; Wilson & Knoblich, 2005).

It does not appear that this cortical system directly transforms perceived motion information into action commands. Activation of mirror neurons in monkeys did not occur when an action was mimicked without an object (Gallese et al., 1996). Umiltà and colleagues (2001) showed mirror neuron activity during observation of a reaching movement when the object was hidden yet the monkey knew it was present. Kohler and colleagues (2002) showed mirror neuron activity in monkeys for a recognizable action sound (e.g., ripping paper, breaking a peanut). As a result of this work and similar findings in humans, Rumiati and colleagues (2005) proposed a dual-route theory of imitation. A direct route or mechanism enables novel actions to be transformed into motor output, and a semantic mechanism allows reproduction of known actions through stored memories. It has been shown that meaningful actions (i.e., pantomime of hammering or writing) and meaningless actions (i.e., nonsensical hand movements) activate different cortical areas (Decety et al., 1997; Grezes, Costes, & Decety, 1998). Meaningful actions engage the left frontal and temporal regions (areas associated with the MNS), whereas meaningless actions mainly engage the right occipitoparietal pathway. By examining strategy selection during action imitation, Tessari, Bosanac, and Rumiati (2006) showed that once a meaningless action was acquired, it was then processed in a manner similar to meaningful actions. Similar dissociations in cortical areas have been shown as a result of practice expertise, as discussed later (e.g., Calvo-Merino, Glaser, Grezes, Passingham, & Haggard, 2005). One of the implications of this dual-route theory is that the more meaningful an action is perceived to be, the more likely it is to engage the MNS. Therefore, demonstrating an action within its appropriate context and keeping it goal directed should be a requirement for observational practice and learning.

Behavioral evidence suggests that the translation between action and perception is relatively direct and bidirectional. Hecht, Vogt, and Prinz (2001) controlled motor and visual experience and showed that participants who only received physical practice of a relative timing movement improved visual judgments on a related task, which they called *action–perception transfer*. Similar results have been shown for the production and discrimination of a gait pattern displayed via point of lights at the joints (Casile & Giese, 2006) and for the perception of limb position when the observer is moving (Reed & Farah, 1995). The bidirectional nature of translation between perception and action is strong support for the idea that both processes share a common neurological pathway. From an observational learning perspective, these findings raise interesting questions about the utility of demonstrations in some situations in view of the dependency of perception on action experience. These issues are discussed further when we consider observer and model interactions.

Evidence for direct matching also comes from studies showing that visual perception affects the execution of a related but irrelevant action. For example, Kilner, Paulignan, and Blackmore (2003) studied participants making sinusoidal arm movements during observation of either a human or robotic arm making similar or dissimilar movements. Participants' movements were negatively affected by observation of dissimilar human movements only, suggesting that perception of incongruent biological motion interfered with action generation. Similar interference effects have been shown for participants observing one point of light moving along a biologically realistic trajectory incongruent to the participant. No interference effects were observed when the trajectory was artificial (Bouquet, Gaurier, Shipley, Toussaint, & Blandin, 2007). Observation of task-irrelevant actions can also facilitate action in what is called

visuomotor priming (e.g., Brass, Bekkering, & Prinz, 2001; Brass, Bekkering, Wohlschläger, & Prinz, 2000). Motor–visual priming has also been demonstrated in which preparation of the movement affects future processing of visual information. When participants were asked to prepare a grasping movement before a visual prime, the grasping responses were faster if the visual prime was compatible with the end state of the prepared movement (Craighero, Bello, Fadiga, & Rizzolatti, 2002; Miall et al., 2006; Vogt, Taylor, & Hopkins, 2003).

The eye movements that participants show in response to observed manipulative actions have also been presented as evidence for the direct matching hypothesis. Direct matching manifests itself if observers show evidence that they are implementing covert action plans in real time with the actor (Flanagan & Johansson, 2003; Rotman, Troje, Johansson, & Flanagan, 2006). Flanagan and Johansson (2003) found that the eye movements of participants observing actors who were performing a block-stacking task were similar to, and in phase with, the eye movements they produced when they performed the task themselves. In both instances, attention was directed proactively to the upcoming point of contact. When observers cannot see the actor's hand, their behavior is no longer coupled to the gaze of the actor but is instead reactive (Falck-Ytter, Gredebäck, & von Hofsten, 2006).

The common-coding framework has been developed further into the theory of event coding (Hommel, Musseler, Aschersleben, & Prinz, 2001), also referred to as *ideomotor theory* (Prinz, 2002, 2005) based on early ideas of James (1890). These theories suggest that voluntary actions are initiated by anticipatory ideas or representations. Actions are automatically activated by anticipation of their effects. Similarly, actions are automatically activated by visual events that

correspond to these effects. Therefore, observation can be an alternative mechanism to action initiation.

Despite evidence suggesting that perception and action are closely linked during observation, as with the neurophysiological literature, it is unlikely that matching is as direct as implied by the term itself (see Decety & Grezes, 1999, for a review). Meltzoff (2002) has acknowledged that direct matching in newborns becomes less direct with age and involves more understanding of the intentions of the model (e.g., Gergely, Bekkering, & Kiraly, 2002). Young children will often imitate the outcome or intended goal of the movement, such as reaching to touch their ear, but not the means, such as reaching across the body (Bekkering, Wohlschlagel, & Gattis, 2000; Wohlschlagel, Gattis, & Bekkering, 2003). On the basis of this work, Wohlschlagel and colleagues (2003) developed the theory of goal-directed imitation (GOADI). Action reproduction and imitation are based on emulatory processes that result in achievement of the outcome by the most efficient means. The imitation process is based on a decomposition of the observed action and its ordering into a hierarchy of goals and subgoals. At the top of the hierarchy is the outcome of the action, which is given more importance than the process by which the outcome is achieved when these differ.

In support of these ideas, it has been shown that observation of both process (i.e., grasping and moving without an action goal) and outcome (i.e., placing) results in similar cortical activation of the DLPFC, which is thought to be involved in action goal representation (Chaminade, Meltzoff, & Decety, 2002). The authors interpreted this result as evidence that the goal of the action is constructed even if it is not present during observation—that is, making the action meaningful

(see also Kohler et al., 2002; Umiltà et al., 2001). The GOADI approach is consistent with the dual-route theory described earlier since meaningful actions should involve a concrete action goal. Observation of meaningful, goal-related behaviors would result in more activation of the MNS and thus allow for easier imitation. However, there is evidence showing that MNS activity increases when attention is directed toward the means rather than the outcome of the action (Hesse & Fink, 2007) and that distal goals do not always take precedence in imitation, particularly when action features are highlighted (see Bird, Brindley, Leighton, & Heyes, 2008).

Thus, the advance of technology has provided extensive evidence for a neurophysiological mechanism by which perception can be translated into action. The discovery of the MNS has led to a number of theories detailing how observation can lead to the acquisition and improved performance of a motor skill. Additionally, considerable behavioral evidence speaks to commonalities of perception and action. It is evident, however, that matching perception to action is not as direct as first imagined but rather involves understanding and experience with the task, especially if observation is used to guide the learning process. It is still unclear whether this necessitates two routes to action (a qualitative difference as a function of task) or just differential activation in similar areas (a quantitative difference).

Visual Perception Perspective

<txni>It is unlikely that imitation is governed explicitly by a direct perception-to-action matching mechanism such that an exact copy of the observed action is imitated. An observational learning perspective that seems to be based primarily on this assumption is the visual perception perspective (VPP) proposed by Scully and Newell (1985). Although there have

been issues concerning the link between perception and movement reproduction, this perspective has played an important role in observational learning research, prompting the question as to what visual information is used by the observer during the observation learning process.

VPP is based on motion and perception research (e.g., Johansson, 1971) and Newell's (1985) model of motor learning. Common to these approaches is the idea that the acquisition of coordination (i.e., the relationship between joints and effectors) defines the initial stage of learning with respect to both observing and performing. In VPP, people are believed to be directly attuned to coordination information through the perception of biological motion (Johansson, 1971, 1973, 1975). Johansson showed that movements presented in point-light form were automatically identified (within about 100 ms) through the motions of individual elements relative to each other (i.e., relative motion). VPP links the concept of relative motion to motor control and coordination (Kugler, Kelso, & Turvey, 1980, 1982; Newell, 1985). The immediate problem for a learner is coordinating the many degrees of freedom of the motor system. Because actions are identified (and described) by the relative motions of the body and limbs, this information was believed to be essential and directly extracted and imitated during observational learning.

Although there is evidence that relative motion is an important constraining source of information for perception, other sources of information appear to be just as or even more important for observational learning when motor learning is required. As detailed in the GOADI account of learning, the means (relative motion) do not always dominate observational learning. Attempts to make relative motion salient through point-light models have failed to produce

beneficial effects (e.g., Al-Abood et al., 2001; Horn, Williams, Scott, & Hodges, 2005; Scully & Carnegie, 1998), and in some cases these point-light models have been detrimental relative to video models (e.g., Hayes, Hodges, Scott, Horn, & Williams, 2007; Romack, 1995).

To directly examine the importance of relative motion information for action reproduction, Hodges, Hayes, Breslin, and Williams (2005) removed this information in a kicking task. One observation group viewed only the toe marker (i.e., no relative motion information), a second group observed two points of light pertaining to the foot (toe and ankle), and a third group viewed three points of light pertaining to the lower leg (toe, ankle, and knee). No other contextual cues were presented to show that a kicking action was required, although participants realized what joints the markers represented. The toe-marker group approximated the model's coordination profile as well as, and in some instances (e.g., hip-knee coordination) better than, the foot or leg groups. When the three groups transferred and observed a full-body relative motion model, there was no significant improvement in the coordination profiles, indicating that end-point information was the constraining source of information for action reproduction. In the final phase of the experiment, participants were required to imitate the action conveyed by the model in order to propel a ball over a height barrier to land on a target. The requirement to achieve an external goal led to the closest approximation of the model's intralimb coordination pattern.

Based on these data, there are two findings that call into question the importance of relative motion for successful observational learning. First, it seems that end-point information was sufficient to successfully imitate a full-body movement. This suggests that at least part of the

imitation process is based on action understanding, where the person is able to fill in the gaps. Relative motion is not imitated in a direct fashion (see also Umiltà et al., 2001). Second, the variable that brought about the closest approximation of the model's intralimb coordination pattern was the requirement to propel a ball. A change in a person's coordination profile to more closely approximate a model should not be taken as evidence that relative motion was used during learning.

These findings have been partially replicated in experiments involving overarm cricket bowling and lawn bowling actions for which the action has been presented in whole-body video and point-light display (PLD) formats, as well as partial PLD format (see Hayes, Hodges, Huys, & Williams, 2007, and Hayes et al., 2007, for details of underarm bowling task and methods; see Breslin, Hodges, & Williams, in press, and Breslin, Hodges, Williams, Kremer, & Curran, 2005, 2006, for details of the cricket bowling action and manipulations). Rather than end-point information alone, it appears that end-effector information (i.e., the bowling arm, rather than just motions of the wrist) is an important source of information during observational learning of whole-body actions.. From these experiments, Breslin and colleagues suggested that during goal-directed imitation, people adopt a local processing strategy (see Mataric & Pomplun, 1998; Mather, Radford, & West, 1992) in which attention is directed toward the motion of a distal effector. This suggestion would be congruent with the GOADI theory of movement imitation. This does not mean that relative motions are not perceived; rather, it means that this information, particularly at a between-limb level, is not necessarily prioritized during observational learning (see Pinto & Shiffrar, 1999).

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<tx>There is also evidence that the end point of the action does not even have to be in direct contact with the body for it to be useful in bringing about the desired coordination pattern. Participants who observed and received feedback pertaining to only the trajectory of the ball in a kicking task showed better retention than participants who observed only the model (Hodges, Hayes, Eaves, Horn, & Williams, 2006). In line with this finding is evidence that actions are planned and executed based on anticipation of their end effects (see Ford, Hodges, & Williams, 2005, Ford, Hodges, Huys, & Williams, 2006; Koch, Keller, & Prinz, 2004), and hence this type of strategy encouraged through outcome-based demonstrations might be fruitful for teaching movement skills. As noted in neuroimaging studies (e.g., Umiltà et al., 2001), there is no reason for the observer to actually see the action to engage the MNS. As long as an action is implied and there is some correspondence between the action and the object, motor skill acquisition can take place through observation of an object's trajectory.

A few researchers have attempted to more directly examine the information used in observational learning using eye tracking techniques. Because the point of gaze does not guarantee the extraction of visual information from that location, visual search evidence is also an indirect supposition of both the information used and the guiding, underlying processes. Mataric and Pomplun (1998) found that when participants watched arm, hand, and finger movements, they consistently fixated on the end point, arguing that an internal kinematic model of the action helped the observer fill in the gaps. Horn and colleagues (2002) did not find consistent end-point tracking during observational learning of a kicking motion. However,

tracking of the foot did generally decrease as a function of practice and observation for the video group, perhaps suggesting that this information is prioritized early in learning. In a later study, this narrowing of search was seen only among participants who did not show improvements in movement form (Horn et al., 2005).

<txni> In summary, we have reviewed key theoretical approaches that affect research in observational learning (see table 17.1). We have differentiated these approaches based on their emphasis on cognitive processes mediating observation and action. To date, the social learning model of Bandura has had the greatest influence on the field of observational learning. However, methodological and theoretical advances in neurophysiology are starting to influence the way mainstream behavioral and neuroscience researchers think about observational learning. In particular, the sophisticated resonance that can take place during observation (as evidenced by MNS activation) allows a mechanism for information transfer in the absence of memory stores and cognitive representations of the act. This does not mean that some sort of image or representation of the act does not guide movement reproduction during physical practice; rather, it means that motor learning can take place during observation (i.e., early mediation) such that the details of the act do not need to be contained within any representation of the act. If observation and action share common neurological pathways, observation would supposedly assist the learner in a manner similar to that of physical practice. However, because overt action is inhibited during observation, the learner would not receive any feedback during observation, thus limiting the information required to adjust future skill attempts.

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Our section on the VPP provided data on the type of information used during observational learning. Although there does not seem to be a definitive information source guiding observational learning, there is evidence that the learner is goal oriented, which promotes a distal focus on the end effector. Most theorists acknowledge that the observational learning process likely depends on a number of factors, such as the task, model, and observer characteristics, and as such the route to learning is quite complex. The GOADI theory (Wohlschlagel et al., 2003), in which imitation depends on the goals and intentions of the learner, is one theory where this task dependency is an inherent feature of the model. As well, the dual-route model of imitation proposed by Rumiati and colleagues (2005) offers a neurophysiological explanation for discrepancies in observational learning research based on the type of action and characteristics of the model and observer. Next we review how these characteristics affect observational learning and consider the empirical evidence in view of the theories discussed thus far.

Task Characteristics

We will examine the role of task characteristics in affecting the observational learning process first in terms of behavioral data then in view of neurophysiological evidence. The previously mentioned meta-analysis outlining the benefits of observational learning (Ashford et al., 2006) revealed different effects of modeling depending on the type of motor skill.

Observation was most beneficial for serial or sequencing tasks (involving several subtasks), with reduced effects for continuous tasks and smallest effects for discrete tasks. According to these

findings, tasks that emphasize memory and cognition are more susceptible to positive observational learning effects than are tasks that emphasize motor learning. Ashford and colleagues (2006) also noted that positive effects of observational learning were typically obtained from studies involving a small range of relatively simple skills that had limited interactions among the components. There has been considerable discrepancy in research findings related to observational learning when multilimb coordination movements have been examined. For example, Whiting, Bijlard, and den Brinker (1987) showed benefits from observing a model performing on a ski-simulator task, yet they failed to replicate this result in a later study. In what they referred to as *discovery learning*, they even found that not watching a model was more beneficial for performance compared with watching the model (Vereijken & Whiting, 1990). In the latter study, the authors attributed the poor performance during observation to goal confusion (Gentile, 1972; Whiting & den Brinker, 1982), where attention becomes divided between the task demands and the movements of the model (see Hodges & Franks, 2002b, for further discussion on this topic).

<tx>In tasks requiring the acquisition of a difficult, continuous, bimanual coordination pattern, where the limbs are offset by 90° relative phase, demonstrations have also been found to be relatively ineffective at conveying the desired movement (Hodges, Chua, & Franks, 2003; Hodges & Franks, 2000, 2001, 2002a). The most effective method of acquisition in these experiments was providing the learner with augmented feedback that displayed the trajectory of one limb as a function of the other so that correct performance resulted in a circular pattern (see also Lee, Swinnen, & Verschueren, 1995). This strategy arguably helped make the task more meaningful in that participants now had a goal to achieve (i.e., make a circle) rather than just an

abstract movement to copy. Experiments are currently underway to determine whether perception of the means (i.e., a model performing a difficult coordination pattern) changes as a function of practice such that understanding develops as a result of motor experience—that is, action-to-perception transfer (e.g., Edwards, et al., 2008; Maslovat, Hodges, Krigolson & Handy, 2009)). However, there has been evidence that observational practice of a model performing a single-limb, between-joint (rather than between-limb) coordination task facilitates later performance of that skill (Buchanan, Ryu, Zihlman, & Wright, in press). It appears that these differences are due to task-related factors, rather than factors related to the skill of the model and the amount and type of feedback (Maslovat et al., 2009). Further, observers are relatively proficient at performing the motion pattern of a model within a limb (such as the arm during an overarm cricket bowl), yet they are less proficient at modeling the required relative motions of the two arms (Breslin et al., 2006; in-press).

Another determinant of modeling effectiveness pertains to how the goals of the task are achieved and measured. Learning effects associated with observation have generally been stronger for measures of movement form versus movement outcome, although these results are task dependent (Ashford et al., 2006). For example, when the task environment does not have an explicit outcome goal, as in learning a ballet technique (e.g., Scully & Carnegie, 1998), the model's movement pattern is the primary goal and observing for imitation purposes is elevated in importance. This was shown in two studies by Horn and colleagues (2002, 2005). When the task had competing goals, such as imitating the model's movement (soccer kick) and attaining the outcome (landing the ball on a target), learners prioritized the external-outcome goal at the expense of imitating the model's movement. We have illustrated the results from these two

studies in figure 17.1, where the hip–knee coordination patterns of two expert models have been compared with those of typical participants as angle–angle plots. Only general strategic features of the action were imitated, such as the number of approach steps to the ball, and not the general relative motion pattern. In support of conclusions from the meta-analysis by Ashford and colleagues, seeing a model did not lead to improvements in outcome, and improvements in movement form were observed only when feedback about task success was withheld. In a subsequent experiment, a direct manipulation of task goal feedback was made. Adult and child observers were asked to imitate a lawn bowling action either with or without a ball (Hayes, Hodges, Scott, Horn, & Williams, 2007). They were scored based on similarity to the model in terms of the step and lunge pattern. As illustrated in figure 17.2, the lunge was more correctly imitated when there was no additional outcome goal (no ball) and hence feedback about performance. The children who bowled with a ball made no improvements in form scores compared with the no-ball group.

\insert figure 17.1 here\

<fc>Figure 17.1 Hip–knee angle–angle plots illustrating the kinematics from two expert models in comparison with movements in retention (after 15 observation trials) from typical participants in the studies by (a) Horn and colleagues (2002) and (b) Horn and colleagues (2005).

<cl>Figure 17.1 adapted from Horn & Williams, 2004).

\insert figure 17.2 here\

<fc>Figure 17.2 A comparison of form scores during observational learning of an underarm lawn bowling technique across two blocks of practice (B1 and B2) and in a retention test for four groups of adults and children bowling with and without a ball.

<cl>Adapted from Hayes et al. (2007).

<tx>When the external goal within a motor task can be solved in different ways, there might be no outcome performance advantage in adopting the technique demonstrated by the model. For example, comparisons of a demonstration and control group during the acquisition of an underarm dart throw by Al-Abood and coworkers (2001) showed that the control group adopted a different action than the model and the demonstration groups adopted (e.g., standard overarm dart throw), but there was no difference in outcome performance across the groups. This result is a prediction from VPP, whereby coordination (form) is facilitated by demonstrations but features related to scaling of the movement, such as timing and accuracy, are facilitated by physical practice (yet see Blandin, Lhuisset, & Proteau, 1999; Hayes, et al., 2006).

In contrast, when the task outcome goal is directly linked to a specific coordination pattern, having access to a model is more helpful. In a three-ball juggling task, Hayes, Ashford, and Bennett (2008) found that observational learning conditions were better for performance and learning than a control condition where only basic verbal instructions were provided. In this case, the juggling movement was not acquired in the control condition. A visual demonstration encouraged the adoption of the desired movement and hence the ability to juggle. It is not clear what the important information within the demonstration was, however. If participants only saw the trajectory of the balls without the trajectory of the hands, would this be sufficient to

encourage learning, or is the interaction between the two necessary? Furthermore, because observation conditions were not examined independently of physical practice, it is not possible to make conclusions about early and late mediation and hence whether the demonstrations alone were sufficient to bring about learning.

In summary, evidence suggests that the effectiveness of demonstrations for motor learning depends on a number of task-related factors, including whether the task is goal or outcome oriented compared with tasks where the movement is the goal of the action, whether the primary measure of performance is outcome or form based, and whether the task comprises discrete components that require sequencing together versus a task requiring interacting components and continuous movements. Because of the goal-dependent nature of these findings, it would appear that the GOADI theory of movement imitation is a good candidate explanation for these discrepant findings. As detailed next, task dependencies might also have a cortical explanation related to judgments of meaningfulness and goal directedness.

<txni>In an attempt to understand the link between perception and understanding, researchers have examined what types of activities elicit human MNS activation during observation. Activation has been shown for both transitive (i.e., tool- or object-oriented) and intransitive (i.e., meaningless or non-object-oriented) actions across various effectors, including hand, mouth, and foot (e.g., Buccino et al., 2001; Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995; Grezes, Armony, Rowe, & Passingham, 2003). Cortical activation is decreased for observed movements that are robotic rather than biological (Tai, Scherfler, Brooks, Sawamoto, & Castiello, 2004), virtual rather than real (Perani et al., 2001), and biologically impossible rather than possible (Stevens,

Fonlupt, Shiffrar, & Decety, 2000). These results have led to the hypothesis that MNS activity is seen only during observations of actions that the observer can physically produce. These results are congruent with dual-route theories outlined earlier since the goals and means of the movement cannot be constructed for actions the observer cannot perform and hence the actions would be considered meaningless. These findings raise the question as to the usefulness of demonstrations in encouraging movements that are not part of the observer's repertoire (an important goal in early learning). It might be that this initial route for the learning of novel tasks is primarily cognitive, occurring via late mediation. Difficult or unusual movements are strategized and represented explicitly. At a representational level, the action system would have little or no involvement until physical practice takes place. This action experience that emerges as a result of practice now informs perception.

<tx>However, there is evidence to show that impossible and meaningless movements should perhaps be considered on a continuum or on an individual or task basis. When seemingly impossible human movements can be made to look possible (by exaggerating certain movements), the goal and general meaning of the action can be constructed, leading to activation of the MNS (Candidi, Urgesi, Ionta, & Aglioti, 2007). In a related study, Gazzola, Rizzolatti, Wicker, and Keysers (2007) hypothesized that the lack of activation in previous studies involving robotic actions (e.g., Tai et al., 2004) may have been a result of repetitive presentation of the same video stimuli. By using different robotic movements within an observation block rather than the same movement each time, Gazzola and colleagues (2007) were able to elicit MNS activation (see also Press, Gillmeister, & Heyes, 2007, who showed that practice moderates activation of the MNS for robotic movements). A similar desensitization effect was

observed by Hamilton and Grafton (2006), who showed that repeated observation of identical movies resulted in decreased MNS activation (i.e., habituation). This latter finding supports the use of learning rather than expert models in facilitating observational practice (see also Mattar & Gribble, 2005). Similar arguments exist concerning MNS involvement during early or late learning, as detailed later. These findings show that the MNS is tasked with making sense of actions, not just resonating with actions that already make sense.

Indeed, understanding of the action appears to be more important than being able to actually perform the movement. For example, observation of a biologically impossible movement showed different interference effects (in terms of movement error) if the participants were told the movement was performed by a human versus a computer (Stanley, Gowen, & Miall, 2007). It has also been shown that the MNS codes the same observed action differently depending on the complexity (Molnar-Szakacs, Kaplan, Greenfield, & Iacoboni, 2006) and perceived intention of the movement (i.e., grasping a cup to drink versus grasping a cup to clear a table; see Iacoboni et al., 2005).

Collectively, these results provide strong support for the involvement of the MNS in action understanding rather than simply action recognition. The perception and understanding of the task by the observer affects MNS activity and thus potentially the effectiveness of observational learning, as discussed later. Although there is evidence that MNS involvement is greater when the task is meaningful to the observer, this does not imply that only easy tasks within the performer's repertoire activate the MNS.

<c>Model Skill Level

<txni>Much of the initial work involving observational learning focused on the model's characteristics and their influence on the learner's performance. Bandura (1977) predicted that observers would pay more attention to models that are more skilled, higher status, and the same sex as the learner. A highly skilled model should create a more accurate cognitive representation and thus result in increased learning, at least from a late-mediation view of observational learning. Early examination of model type showed that model skill level was not important when participants were required to learn a skill of low cognitive demand, such as rolling a ball to a target, versus a skill of high cognitive demand, such as having to employ a strategy to get the ball to the target (Martens et al., 1976).

<tx>Landers and Landers (1973) manipulated skill level (high versus low) and status (teacher versus peer) of the model during observational learning of the Bachman ladder-climbing task. Participants who observed the skilled teacher performed the best at the task, whereas participants who observed the peer model performed better when the model was of low rather than high skill level. The fact that an expert model was more effective in encouraging learning supports late-mediation views of learning, in which the quality of the acquired cognitive representation of the desired movement dictates accuracy of movement replication. However, the fact that a low-skill peer model was better than a high-skill model seems to support early mediation accounts of observational learning. Increased similarity between the observer and model might result in greater covert action simulation, especially if there is variability across trials, as would be

expected with a learning model (Hamilton & Grafton, 2006; yet see Desy & Theoret, 2007, for alternative findings regarding model similarity).

<tx>When peer models were used to convey a swimming stroke, skilled models were more effective than novice models for observational learning (d'Arripe-Longueville, Gernigon, Huet, Cadopi, & Winnykamen, 2002). The authors attributed this result to increased motivation by the observer to emulate the skilled model and thus work harder in practice. Other authors have failed to show differences between models of differing skill levels (learning versus expert) on a computer video-game task (Pollock & Lee, 1992) or a weightlifting task (Lee & White, 1990; McCullagh & Meyer, 1997). These equivocal results have been attributed to task differences, such as the difficulty of the task, and the lack of control over model status (e.g., Weir & Leavitt, 1990).

Learning models allow the observer to determine the information that is most related to task success, since only specific actions result in desirable outcomes. This information would not be as salient in observation of repetitive, correct performance (Pollock & Lee, 1992). Furthermore, actions would be modified as a result of errors, resulting in the observer being more engaged in the cognitive problem-solving processes (Adams, 1986). In support of this latter argument, Adams (1986) found that improvements in learning a timing task were observed only if the model's feedback was also available to the observer, arguably engaging the learner in the process of error correction (see also Herbert & Landin, 1994; Hodges et al., 2003; McCullagh & Caird, 1990). The possible benefits of a learning model have been further underscored by neurophysiological evidence (EEG) showing that motor-related areas in the brain that are

activated when observers view a person making errors are similar to the areas that are activated when errors are self-generated (van Schie, Mars, Coles, & Bekkering, 2004). It seems the observer needs to see the conflict between the desired and actual movement in order to engage the motor (or MNS) system to learn through observational practice alone (e.g., Mattar & Gribble, 2005).

<c>Model Status and Similarity

<txni>Skill level of the model can affect both cognitive effort and the degree of covert motor simulation during observation (i.e., both late and early mediation). How the model is perceived could also affect these observational learning processes. Effects of model status could be due to attention differences (as hypothesized by Bandura, 1977), differences in information presented by the model, or the perception of different information due to the learner being more motivated and concentrating harder on imitation (Gould & Roberts, 1981). Evidence against the first hypothesis was provided by McCullagh (1986), who found that regardless of whether participants were cued to the status of the model before or after observation, participants who viewed a high-status model performed better on the Bachman ladder-climbing task than participants who viewed a low-status model.

<tx>Model similarity has been shown to be an important variable mediating the effectiveness of observational learning. Same-sex models are more beneficial than opposite-sex models for observational learning (e.g., Griffin & Meaney, 2000). One way to control for model similarity is to use learners as their own model. However, simply watching oneself on videotape has not proved to be an effective strategy (Newell, 1981; see Rothstein & Arnold, 1976, for a review).

This may be because learners do not need to see all their performances. It may be more effective to select good trials and remove those containing undesirable performance (see Dowrick, 1999, for a review). In addition, augmenting video observation with verbal (and visual) helps focus the learner's attention on the salient features of the presentation (e.g., Janelle, Champenoy, Coombes, & Mousseau, 2003). Further testing is necessary to determine whether these effects are motivationally mediated or a result of early mediation such that the more similar the model is to the observer, the more likely the motor system is engaged during observation.

<c>Model–Observer Interactions and Observer Experience

<txni>If action understanding is a key requirement for activation of the MNS during observation, a question that has arisen is whether watching an unfamiliar movement (one that is not in the observer's motor repertoire) will result in MNS activity. If the observer does not have the necessary experience with a task to understand the actions or goals of a movement, will a demonstration activate MNS circuitry? Observation of someone playing a piano produced greater motor cortical activation in pianists than in musically naive participants, although no differences were found during observation of control stimuli involving finger and thumb movements (Haslinger et al., 2005). When skilled dancers observed similar movement patterns from two dance styles that were either familiar or unfamiliar, MNS activity was observed only for movements that were within the observer's motor repertoire (Calvo-Merino et al., 2005; Calvo-Merino, Grezes, Glaser, Passingham, & Haggard, 2006).

<tx>The differential MNS activity for learned versus unlearned movements suggests that this activation develops during the learning process. Although there is considerable evidence that the

cortical connections mediating motor activation through observation are formed through experience (see Brass & Heyes, 2005, and Kelly & Garavan, 2005, for reviews), few studies have examined how MNS activation changes as a function of practice. Examination of the change in MNS activation during the learning process may help clarify how observational learning occurs. One exception was a study in which expert dancers practiced a new dance sequence for 5 wk, with observation and fMRI recordings of the practiced movement and a nonpracticed movement interspersed within each week of the acquisition phase (Cross, Hamilton, & Grafton, 2006). Increased activity in MNS areas occurred during the learning process for the practiced movement. It would also be worthwhile to examine whether changes in MNS activation occur with observational practice (i.e., without physical practice). If motor practice is necessary for MNS activation, it would seem that the information obtained through observation is more cognitive or strategic in nature.

One limitation of some studies examining expertise differences in MNS activation (i.e., Calvo-Merino et al., 2005, 2006) is that the observers were instructed to evaluate the movement based on symmetry or perception of effort rather than with the goal of imitating the movement. Instructions have been shown to affect cortical activity; more activity occurs in the brain structures associated with action planning when imitative instructions versus evaluative instructions are given (Decety et al., 1997; Zentgraf et al., 2005). In contrast to the findings of Calvo-Merino and colleagues, motor activation has been shown for observation of unfamiliar movements when imitation was required. Buccino and colleagues (2004) had nonguitarists imitate unfamiliar guitar chords. They showed MNS activation during observation, preparation, and imitation. Increased MNS activity has also been seen in the early stages of imitative

learning, a result again attributed to instructions requiring reproduction of the task (Vogt et al., 2007).

These effects of the learner's intention are similar to the intention superiority effect seen in behavioral studies. When observers were told that they would have to reproduce an observed motor skill (e.g., a key-press, timing task), they performed significantly better during retention than observers who were told they would only have to recognize or describe the task (Badets, Bladin, Bouquet, & Shea, 2006; Badets, Blandin, & Shea, 2006). The differences were mainly in terms of relative timing rather than absolute timing, suggesting that intention moderated what information was attended and observed, perhaps encouraging early mediation.

<txni> In summary, the effectiveness of modeling depends on an interaction of several factors, including the characteristics of the model, the observer, and the task being learned. We have summarized the general research areas and methods along with some examples in table 17.2. Although practitioners are often hoping for a golden rule to use with modeling, such a rule may not be possible due to the complexity of the interaction. Not all tasks and skills respond equally to observational learning, particularly when the goals and means of the movement are different. Thus, important considerations when evaluating the success of observational learning include the task requirements (i.e., outcome versus process) and how they will be evaluated. There is clear evidence that the type of model affects the observer's motivation and attention, which in turn affects the learning process. Although research in this area has not provided a consensus regarding optimal model characteristics, it helps if the learner can adequately determine the proper performance of the skill and if feedback is available regarding both the model's

performance and the observer's own performance (during observational learning), facilitating error detection and correction.

Finally, the observer's mind-set affects observational learning. Intention to reproduce the observed movement affects later performance, which can be influenced by the instructions.

Although the interaction of task, model, and observer characteristics makes it difficult to establish guidelines for modeling, it is hoped that neurophysiological techniques will advance our understanding of these interactions, at least in terms of motor involvement during observation, so that more specific behavioral recommendations can be made.

\insert table 17.2 here\

Conclusions and Future Directions

In this review, we have outlined the major theories that influence thinking and empirical research about observational learning. We have focused on the implications of these theories for behavioral research and ways of modifying the learning process. In discussing how various characteristics play a role in the observational learning process, we have highlighted factors to consider when designing effective procedures for observational learning, as well as drawn attention to areas of debate in this field. It is difficult to draw general conclusions across studies because of the experimental inconsistency regarding instructions, provision of feedback, and conveyance of the goals of the action. In addition, studies have varied as to whether goals are means or outcome oriented and hence have varied in how performance is assessed in terms of these measures.

<tx>Continued research on demonstrations may help clarify the mechanisms by which observation benefits learning, thus providing clearer guidelines for practitioners. Further exploration comparing observational learning, observational practice, and physical practice at different times in the learning process may clarify the roles of watching versus performing motor skills, particularly if motor skills are examined that place differing emphasis on movement form (dynamics) and outcome attainment (see Weeks & Anderson, 2000). For example, if observational practice provides the learner with primarily strategy-related information, then demonstrations would perhaps be most valuable early in the learning process to speed up acquisition (unless there are benefits from task exploration and discovery learning for later retention and transfer; see Vereijken, 1991).

Future studies will need to consider how demonstrations facilitate learning in terms of early and late mediation and whether one route is better than another with respect to rate of acquisition, retention, and later transfer. In terms of behavioral evidence, effector specificity has been the strongest evidence of motor system involvement during observation (see Heyes & Foster, 2002; Vogt & Thomaschke, 2007). It will be helpful to consider other types of behavioral evidence for and against early mediation, such as performance on related perceptual discrimination tasks and errors in action that could not be attributed to explicit strategy use. This might be achieved through examination of learning models or expert models who make occasional errors that are not consistent with explicit strategy use. Measurement or manipulation of visual gaze or kinematics during the observation phase would also help to indicate the degree of direct motor involvement during observation.

It is also likely that people will acquire the same skill via observation with different degrees of motor system involvement during observation. Although this question has been examined through comparisons of expert and novice performers and as a function of learning, there has not been a systematic attempt to examine the consequences of these different ways of learning and to examine behavioral changes when the motor system is more involved in perception. Potential benefits of observational practice or learning in relation to physical practice also have not been explored. At least with respect to late mediation, there might be more generality in the type of representations acquired through observation, which could be beneficial for transfer.

Of primary importance to the practitioner is how the information gathered can be used to increase the effectiveness of demonstrations during observational learning. One implication is that the instructions given to the observer may change the involvement of the MNS, since observing with the intent to imitate appears to activate more MNS structures than observing with the intent to evaluate activates. In addition, modeled actions must be possible to perform and must be understood by the observer. Understanding appears to be an important determinant of MNS activation, perhaps due to the observer being able to imagine the movement or make the movement more meaningful with respect to task goals (see Milton, Small & Solodkin, 2008).

We have summarized pertinent research involving the examination of observational learning from diverse areas, including traditional behavioral measures, perturbation or occlusion research, eye tracking studies, and neurophysiological techniques. All provide a unique contribution to understanding what information is important during observational learning and how this

information is translated from perception into action. Behavioral measures provide the basics of how the types of task and model characteristics affect learning, but they are limited in their appraisal of what is attended to and how translation occurs. Occlusion (e.g., point-light displays) and eye tracking studies help provide the *what* and neurological studies help provide the *how* of observational learning; so far these areas provide only limited information that can be applied to practical observational learning. As we continue to gain understanding of the mechanisms by which observation benefits performance, we also hope to gain insight into how to accelerate this process and maximize the use of demonstrations in the learning environment.

Although we appreciate that practitioners would like simple guidelines for maximizing learning, the development of skill acquisition is not a simple process, and thus this expectation may be unreasonable. The hope is that future work will involve a coalition of the research in these varied areas to provide a useful framework to guide observational learning. In addition, new technologies and methodologies will provide new avenues of research that further contribute to our understanding of imitative processes. Regardless, it should be evident from this chapter that observation assists the learning process and demonstrations are a useful tool for skill acquisition. However, rather than assuming that any demonstration will naturally lead to maximal performance, careful consideration of skill type, model type, characteristics of the observer, and instructions will lead to guidelines regarding the type and amount of observation to optimize learning.

<lh>Chapter 17

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Figure captions

Figure 1: Hip-knee, joint angle-angle plots illustrating the kinematics from two different expert models in comparison to movements in retention (after 15 observation trials) from typical participants in the studies by Horn et al. (2002; Fig A) and Horn et al. (2003; Fig B).

Figure 2: A comparison of form scores during observational learning of an underarm, lawn bowling technique across two blocks of practice (B1 and B2) and in a retention test for 4 groups of adults and children bowling with and without a ball. Adapted from Hayes et al. (2007).

<tt>Table 17.1 Primary Research Questions and their Associated Methods, and References in Observational Learning Research

<tch>Research area	Primary research questions	Method used to test the question	Research examples
<p data-bbox="139 457 321 632"><tb>What is the representation guiding action?</p>	<p data-bbox="363 348 686 596">Is a motor representation of the movement evoked during its observation, or is it formed during movement production (i.e., early mediation versus late mediation)?</p>	<p data-bbox="712 348 1128 632">Performance of a distracting cognitive task and an unrelated motor task during observation of a force-field perturbation task Sequence learning of serial RT Test for effector dependence in observational practice of finger-sequence serial RT</p>	<p data-bbox="1154 348 1458 522">Mattar & Gribble (2005) Howard et al. (1992) Heyes & Foster (2002); Bird & Heyes (2005)</p>
	<p data-bbox="363 642 673 779">Do observation and action share common neural pathways (i.e., is there common coding)?</p>	<p data-bbox="712 642 1081 779">Imaging tests (e.g., fMRI) of common neural activation during observation and reproduction of movements</p>	<p data-bbox="1154 642 1451 779">di Pellegrino et al. (1992); Gallese et al. (1996); Rizzolatti et al. (1996)</p>
	<p data-bbox="363 789 667 1073">Does perception of the event activate the observed response (i.e., direct matching), or is the response mediated by a memory representation (i.e., semantic, dual route)?</p>	<p data-bbox="712 789 1118 1146">Tests of cortical activation during observation of meaningful and meaningless actions Tests of cortical activation during imitation of actions performed with and without an object Tests of similar eye movements in observers and actors</p>	<p data-bbox="1154 789 1451 1037">Rumiati et al. (2005); Decety et al. (1997); Grezes et al. (1998); Gallese et al. (1996) Flanagan & Johansson, (2003); Rotman et al. (2006)</p>
	<p data-bbox="363 1157 659 1331">Does movement and action experience mediate (and facilitate) perception of the same movement?</p>	<p data-bbox="712 1157 1097 1440">Discrimination of perceptual events (e.g., gait) with and without motor practice Tests of motor–visual priming on RT to a visual stimulus Comparison of motor experts and novices</p>	<p data-bbox="1154 1157 1451 1440">Hecht et al. (2001); Casile & Giese (2006) Craighero et al. (2002); Miall et al. (2006); Vogt et al. (2003) Calvo-Merino et al. (2005, 2006); Buccino et al. (2004)</p>
	<p data-bbox="363 1451 623 1524">Does motor imagery facilitate imitation?</p>	<p data-bbox="712 1451 1081 1524">Tests of activation in cortical motor areas during imagery</p>	<p data-bbox="1154 1451 1451 1551">Decety et al. (1990); Grafton et al. (1996); Tomasino et al. (2007)</p>
<p data-bbox="139 1667 321 1732">What information is</p>	<p data-bbox="363 1562 686 1667">Do observers perceive and use relative motion in the imitation of skills?</p>	<p data-bbox="712 1562 1128 1698">Changes in observer’s relative motion toward that of model Tests of imitation in the absence of relative motion</p>	<p data-bbox="1154 1562 1451 1698">Al-Abood et al. (2001); Horn et al. (2005) Hodges et al. (2005); Breslin et al. (2005)</p>

perceived and imitated?	Do observers emulate the goal of the performer rather than the means (i.e., is there goal-directed imitation)?	Gesture imitation in children Observer's visual search prioritizing the end effector in finger, hand, and arm movements	Bekkering et al. (2000); Bird et al., (2007); Wohlschlagel et al. (2003); Mataric & Pomplun (1998)
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<tt>Table 17.2 Observational Learning Variables and their Associated Research Questions, Methods, and References

<tch>Research area	Primary research questions	Method used to test the question	Research examples
<tb>Task characteristics	Does the effectiveness of observational learning depend on how the goal of the task is achieved (i.e., external goals versus performance of the movement pattern)?	Examination of coordination tasks in which the movement pattern is the goal Manipulation of feedback and task goals	Buchanan et al. (in press); Hodges et al. (2003); Hodges & Franks (2002a, 2002b); Scully & Carnegie (1998) Hayes et al. (2007); Horn et al. (2002, 2005)
	How do understanding and implied meaning of the observed task affect activation of cortical motor areas?	Examination of cortical activation during observation of robotic movements Examination of cortical activation during observation of impossible movements	Gazzola et al. (2007); Press et al. (2007); Tai et al. (2004) Candidi et al. (2007); Stevens et al. (2000)
Model characteristics	Does the observer need to see errors in performance?	Manipulation of model skill level	d'Arripe-Longueville et al. (2002); Landers & Landers (1973); Lee & White (1990); Martens et al. (1976); McCullagh & Meyer (1997); Pollock & Lee (1992)
	Can the type of model affect cognitive effort and degree of motor simulation?	Manipulation of model status and similarity to observer	Griffin & Meaney (2000); McCullagh (1986)
Observer characteristics	Does observer intention affect observational learning?	Manipulation of instructions	Badets, Blandin, Bouquet, et al. (2006); Badets, Blandin, & Shea (2006); Decety et al. (1997); Zentgraf et al. (2005)
	Does the performer need experience with the observed task to activate cortical motor areas?	Comparison of motor experts and novices Examination of within-participant cortical activation changes during skill practice	Buccino et al. (2004); Calvo-Merino et al. (2005, 2006); Haslinger et al. (2005) Cross et al. (2006); Vogt et al. (2007)



