

# Understanding Other People's Actions: Intention and Attention

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This study investigated the extent to which observation of an action performed by a human actor or a robotic arm may kinematically prime the performance of an observer subsequently required to perform a similar action. In Experiment 1, an actor reached for a target presented in isolation or flanked by a distractor object. Subsequently, an observer was required to perform a similar action toward the target object, but always in the absence of the distractor. The kinematics of both the human actor and the observer were affected by the presence of the distractor. Unexpectedly, similar effects were found in the observer's kinematics during the trials in which the actor was seated in front of the observer but no action was demonstrated (catch trials). Results from 4 subsequent experiments suggest that the motor intentions of the actor can be inferred by monitoring his or her gaze. To support this conclusion, results are discussed in terms of recent work spanning many disciplines involved in combining gaze direction and body movements.

Two ladies are happily chatting; one crosses her legs, and after a brief interval the other does the same. This is an example of how people copy an action that someone else has previously performed. Another example is that of picking up a glass in front of a friend. In doing so one might, without the friend's conscious awareness, subsequently elicit in the friend the will to carry out the same action. The notion according to which the perception of certain movements is likely to induce a tendency to perform the same or similar movements has a long standing in psychology and is inherent in James's (1890) ideomotor principle. According to this principle, perceptual induction—that is, induction based on the similarities between events perceived and movements induced—causes an observer to repeat the actions he or she sees happening in a scene.

More recently, Prinz (1987) referred to the class of actions elicited by an actor from people who are not explicitly required to perform any movement as *ideomotor actions* (see also Greenwald, 1970). When an observer perceives somebody else performing a body gesture, the perception of that gesture will tend to activate its execution by the observer. Ideomotor actions are thus a particular type of imitative action characterized by the lack of the underlying intention of the observer to imitate.

A possible explanation for this type of imitative behavior is that action perception activates an action observation–execution matching system that entails a direct matching between the visually perceived input and the motor output (e.g., Butterworth, 1990; Meltzoff, 1995). For instance, evidence that observing actions performed by another individual activates a matching motor pro-

gram by direct perceptual-motor mapping has been provided by Meltzoff and colleagues (e.g., Meltzoff, 1995; Meltzoff & Moore, 1977). On the basis of infant imitation of facial and manual gestures, these authors claimed that humans have the inborn ability to use a supramodal representational system to represent both the body movements they see in others and the body movements they perform themselves.

The strongest support for the existence of an action observation–execution matching system comes from a number of physiological studies that support the notion that motor structures are involved in action perception as well as production, particularly those studies concerned with the so-called mirror neurons in area F5 (F5 neurons) of the premotor cortex of the macaque monkey (e.g., Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti & Arbib, 1998). These F5 neurons are active not only when a monkey grasps and manipulates objects but also when a monkey observes an experimenter performing similar actions. The tuning of the neurons can be quite specific, such that they code only specific features of how an action is executed. For example, particular cell populations are observed to fire during the observation of a grasp movement, but only when the grasping is performed with the index finger and the thumb. Further, the F5 neurons become active even when the final part of the action is hidden and can only be inferred (Umiltá et al., 2001).

Neurons showing similar properties to those in area F5 have also been reported in monkeys within the superior temporal sulcus (STS) by Perrett and colleagues (Oram & Perrett, 1996; Perrett, Harries, Bevan, & Thomas, 1989; Perrett, Rolls, & Caan, 1982). For instance, in the lower bank of the STS, cells sensitive to perceived actions of the hand have been found. The properties of these cells resemble the visual properties of the F5 neurons in the sense that they code for the same types of actions and are nonresponsive to pantomimed hand actions without a target object.

Evidence that an action observation–execution matching system similar to that found in monkeys exists in humans comes from studies using three different methodologies: transcranial magnetic stimulation, functional brain imaging, and kinematics (Castiello, Lusher, Mari, Edwards, & Humphreys, 2002; Fadiga, Fogassi,

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Pavesi, & Rizzolatti, 1995; Grafton, Arbib, Fadiga, & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996). Using transcranial magnetic stimulation, Fadiga et al. (1995) demonstrated a selective increase in motor-evoked potentials when subjects observed various actions. This increase occurred selectively in the muscles that the subjects used to replicate the actions they observed. Two positron emission tomography studies (Grafton et al., 1996; Rizzolatti, Fadiga, Matelli, et al., 1996) have included a condition in which subjects observed an experimenter grasping 3-D objects. Grasp observation significantly activated the STS, the inferior parietal lobule, and the inferior frontal gyrus (BA 44) of the left hemisphere. Using kinematical methods, Castiello et al. (2002) demonstrated that motor priming could occur from the observation of action. Even though the participants in this study were not required explicitly to imitate the model's movement, an automatic modulation of grasp amplitude resulted from viewing another's grasping. In addition, Castiello et al. (2002) asked participants to grasp an object after observing a grasping action performed by either a human model or a robotic hand. Motor priming occurred after the observation of the biological action but was not seen for the robot condition. Following on from these latter findings, an issue at stake in the present article is that of whether an observed action has to be part of the existing behavioral repertoire of the observer in order to trigger motor priming, the unresolved question being whether or not motor priming is selectively tuned to biological action patterns. Recent methodological and theoretical developments make this a particularly timely and tractable issue.

Previous work has suggested that monkeys, in addition to both human adults and children, code or attend to grasping actions performed by a person, but not necessarily to those performed by a mechanical device. These studies suggest that the movements of mechanical, nonbiological movement devices are encoded in a different way than are those movements performed by either humans or other biological systems. For example, F5 and STS neurons no longer fire when a tool instead of a biological effector interacts with an object (Gallese et al., 1996; Perrett et al., 1990). Functional imaging studies of adult humans have also failed to find evidence of either premotor or frontal activation when movements of a schematic hand were observed in a virtual reality system (Decety et al., 1994). Infants react differently to a claw representation of a human hand than to a human hand itself (Woodward, 1998), and they interpret differently the movements performed by a human model and a mechanical device attempting, but failing, to pull apart a dumbbell (Meltzoff, 1995). A possible interpretation of this distinction between mechanical and human models is that infants are more likely to attribute to humans, rather than to mechanical devices, the desire or intention to perform a target action (Heyes, 2001). Consequently, the natural question—the one that I attempt to answer in the present article—is this: What makes humans special? And, further, which are the cues that humans rely on in order to attribute to others the intention to perform a certain action?

Previous attempts to answer this question can be found in the developmental, neuroimaging, and neurophysiological literature. For example, neuroimaging studies have suggested that gaze direction in adult humans is relevant to guiding judgments of intention and intentionality (Puce, Allison, Bentin, Gore, & McCarthy, 1998; Wicker, Michel, Henaff, & Decety, 1998). Similarly, Baron-

Cohen, Campbell, Karmiloff-Smith, Grant, and Walker (1995) identified the use of gaze-direction information as a sophisticated behavior and a cue to others' visual experience and intentions. The results of their study suggest that normal children use eye direction as a cue for reading mental states and that the eyes are the best indicators that people have connected with another mind when engaging joint attention. In a similar vein, Jellema, Baker, Wicker, and Perrett (2000) described a new population of cells, located in the anterior part of the STS in the macaque monkey, that were selective for the observation of reaching actions only when the attention (i.e., gaze direction) of a model was focused on a target. It thus appeared that the direction of attention modulated the responses of the reaching cells such that the response magnitude of these cells reflected the intentionality of the action (Jellema et al., 2000).

The possibility of joint attention and intention mechanisms modulating motor activation during action observation has never been investigated in humans. In humans, does the direction of attention mediate sensorimotor coupling during action observation? Is joint attention between the model and the observer necessary to activate the action observation–execution matching system? The use of interference paradigms may provide partial answers to these questions.

A series of studies has demonstrated that even to-be-ignored objects can be processed in parallel to target objects such that competition between planned-and-executed action toward the target and planned-but-not-executed action toward the to-be-ignored object emerges. In particular, it has been demonstrated that parallel computations for different types of grasp—one for the target and another for the nonattended distractor—may be at the origin of the changes observed in the kinematics of the action directed to the target (for a review, see Castiello, 1999). For example, Castiello (1996) asked participants to grasp a target presented alongside a distractor of a different size and found that the amplitude of peak grip aperture (while en route) toward the target was influenced by the size of the distractor. If the target was small, the amplitude of peak grip aperture was greater when the distractor was large than when the target was grasped in isolation. Conversely, the amplitude of peak grip aperture for the grasp of a large target was less when the distractor was small than when the target was grasped in isolation. It is important to note that interference effects emerged only when some attention was forced on the distractor.

Suppose that an observer is watching a human model grasping a target object in the presence of a distractor object and that the model's movement is affected by the presence of the distractor. Then, suppose that, immediately following the completion of this movement, the observer is required to perform the same action, on the same target object, but without the presence of the distractor object. Will the observer's action be influenced by the observed affected action previously performed by the model? And, if so, will the observer's action observation–execution matching system have been initialized by the direction of the model's overt attention (i.e., gaze direction)—that is, toward the stimuli in the environment (i.e., the target and distractors)?

It is clear that the full-blown idea of an action observation–execution matching system can involve multiple components. Some of these involve attentional and intentional components that have never been investigated in adult humans. Additional work is thus needed to shed light on the mechanisms mediating the par-

ticular type of imitative action characterized by the lack of the underlying intention of the observer to imitate. To this end, the aim of the present study was to explore the question of whether or not imitation of distractor-mediated kinematics depends on the ascription of intentions to biological models.

### Experiment 1

In Experiment 1, I asked participants to observe either a human model or a robotic arm model performing a reach-to-grasp action toward an object presented either in isolation or flanked by a smaller object (distractor). Subsequently, the observer was asked to perform the same action toward the same target object. For the observer, the target object was presented in isolation at all times. If the kinematics of the model's movement to a target differ depending on whether a distractor is present or absent, the kinematics of the observer's subsequent movement should differ as well, even though additional objects are not seen. This effect occurs because, as Castiello et al. (2002) demonstrated, observers can be automatically primed from a kinematical point of view by watching a model performing a similar action.

The dependent variables thought to be specifically relevant to this hypothesis were (a) movement duration, (b) the velocity profile of the arm, and (c) the amplitude of maximum grip aperture. These variables were chosen because consistent results in the reach-to-grasp literature have shown that the reach-to-grasp movement is dependent on the size of the stimuli. In particular, movement duration is longer, deceleration time (the time from the moment of peak velocity to the end of the movement) is prolonged, and the amplitude of the maximum grip aperture is more reduced for smaller than for larger stimuli (e.g., Jakobson & Goodale, 1991). Thus, for a movement toward a large target, if the results showed a longer movement duration, a prolonged deceleration time, or a lowered maximum grip aperture in the presence of a smaller distractor, inferences regarding the influence of the small distractor on the kinematics of both the actor and the observer for movements toward the larger target could be advanced.

### Method

**Participants.** Twenty-four students (16 women and 8 men, ages 20–25 years) volunteered to participate. All were right-handed, reported normal or corrected-to-normal vision, and were unaware of the purpose of the experiment. They attended one experimental session of ~1-hr duration. Half of the participants were randomly assigned to the "model" group, the other half to the "observer" group.

**Robot.** The robotic arm was custom-designed and built by technicians in the Department of Psychology, University of Melbourne, Melbourne, Victoria, Australia. It looked like an average human forearm with a gloved hand, was mounted on a metal frame, and used a single motor to move from a vertical to a horizontal position. The four fingers and the thumb had a common movement, so as to mimic the closing of a human hand. The construction was electromechanical and controlled by an 87C751 microcontroller. The hand was constructed of nylon cords for the tendons, silicon rubber for the joints, and wooden dowels for the bones. Movement was provided by a DC electric motor that tensed the tendons to close the hand. Springs were used to store energy and thus reduce the required power and size of the motor. Limit sensors on the arm and hand were used by the microcontroller to control movement. The arm length was approximately 0.5 m. The maximum pickup weight was approximately 0.1 kg. The movement of the robot was quite smooth, and the folding of the hand was

comparable to a human grasping action. The robot was programmed to move its arm and open its fingers simultaneously when the experimenter pressed a button. The maximum aperture of the fingers (110 mm) was programmed to occur after ~72% of the total movement duration (800 ms) had elapsed. This value corresponds to the occurrence of maximum grip aperture usually found in adult humans when performing a whole hand prehension (Castiello, 1996). After reaching the maximum aperture, the fingers started to close on the to-be-grasped object.

**Type of stimuli.** Stimuli were spheres made of a translucent material and consisted of (a) a 3-D target object (diameter: ~8 cm) positioned at a distance of 30 cm from the hand starting position along the midsagittal plane, (b) a 3-D distractor object of the same size as the target (*same-size distractor*; diameter: ~8 cm), and (c) a 3-D distractor object smaller than the target (*small distractor*; diameter: ~1 cm). The distractor object was presented at 20° to the right or the left of the target (see Figure 1). To illuminate the stimuli, five LEDs were located within both the target and same-size distractor spheres. Three LEDs were inside the small distractor sphere. The LEDs were connected to two metallic contacts on the exterior of the spheres. These contacts met with three other metallic plates (one to the right, one in the center, and one to the left) that were fixed to the table and connected to a PC. The reason for using only a large target object was to allow comparison of the human and the robot movement. The robot could be programmed only to perform a whole hand prehension, the type of grasp typically used in grasping larger objects. The reason for using a distractor object of the same size as, or of a smaller size than, the target was to enable differentiation between the motor output required when reaching to grasp the target stimuli or a same-size distractor (whole hand prehension) and the motor output required when reaching to grasp the small distractor (precision grip). One of the issues at stake in the present article is the implicit activation of motor patterning dictated by the distractor and its competition with the motor output dictated by the target.

**Apparatus.** Reflective passive markers (diameter: 0.25 cm) were attached to (a) the wrist, (b) the index finger, and (c) the thumb of both models and observers. Movements were recorded using an ELITE motion analysis system (Bioengineering Technology & Systems [B|T|S]). Participants (both models and observers) wore lightweight spectacles (Plato Technologies Inc., Toronto, Ontario, Canada) containing liquid crystal lenses, which governed the visual availability of the target and distractor stimuli by changing from opaque to clear on the computer's signal.

**Data processing.** The ELIGRASP software package (B|T|S) was used to analyze the data and provide a 3-D reconstruction of the marker positions as a function of time. The data were then filtered using a finite impulse response linear filter (transition band = 1 Hz, sharpening variable = 2, cutoff frequency = 10 Hz). Movement initiation was taken to be the release of the starting switch. The end of the movement was taken to be the time when the fingers closed on the target and there were no further changes in the distance between the index finger and the thumb.

The statistical analysis was confined to the dependent variables thought to be specifically relevant to the hypothesis under test (specified and justified earlier). These variables were (a) movement duration, (b) the velocity profile of the arm (as measured by the wrist marker; reaching component), and (c) the maximum distance between the two markers positioned on the index finger and the thumb (i.e., amplitude of maximum grip aperture; grasp component).

**Procedure.** The participants assigned to the observer group were tested in two conditions. In one condition the model was human (*human-human*); in the other, the model was a robotic arm (*robot-human*).

**Human-human condition.** Two participants, a model and an observer, were seated facing each other at a table in a darkened room (see Figure 2a). Artificial lighting within the room allowed the model and the observer to see each other and the experimental setup clearly. The black working surface measured 90 × 90 cm and was smooth and homogeneous. Prior to each trial, the model and the observer put their right elbows on their respective starting positions (diameter: 5 cm), 20 cm in front of the

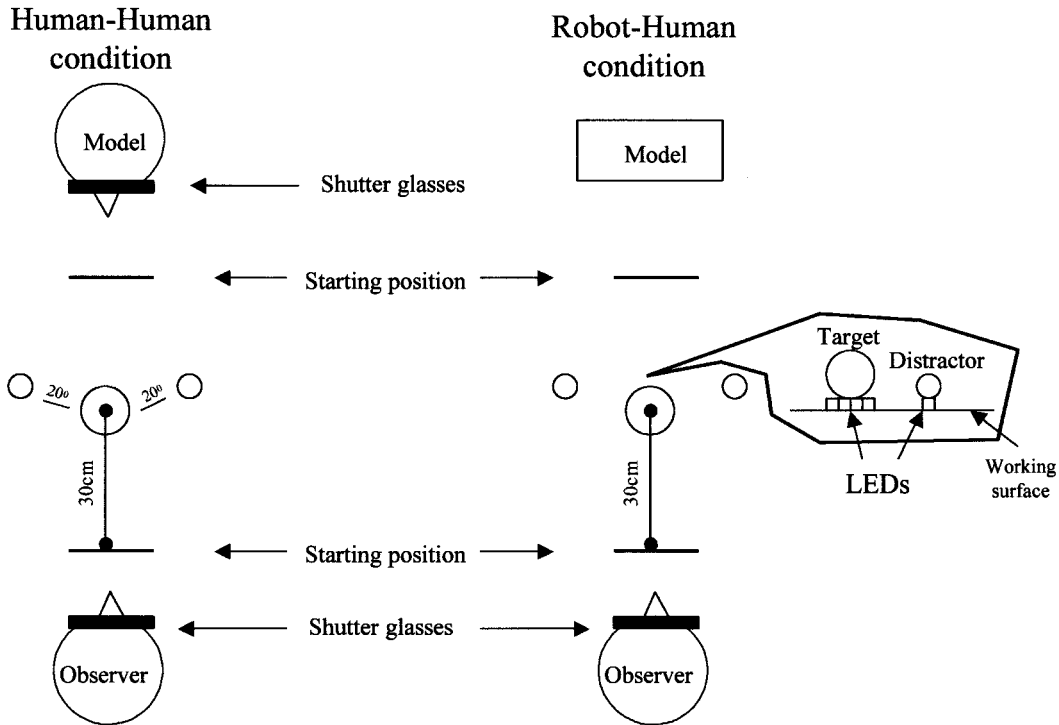


Figure 1. Schematic representation of the experimental setup.

midline. The spectacles of both the observer and the model cleared, and, after a random interval (of 50, 150, 300, or 500 ms), the target and the distractor were illuminated, indicating to the model to reach toward and grasp the target. The target and the distractor remained illuminated throughout the duration of the trial. Then the observer's spectacles were

shut, and the experimenter removed the distractor object. After this operation, the observer's spectacles were reopened, and he or she was required to reach toward and grasp the target object positioned in front of him or her (*standard trials*). The time from when the observer's spectacles were shut and when they were subsequently reopened varied between 1 and 2 s. For

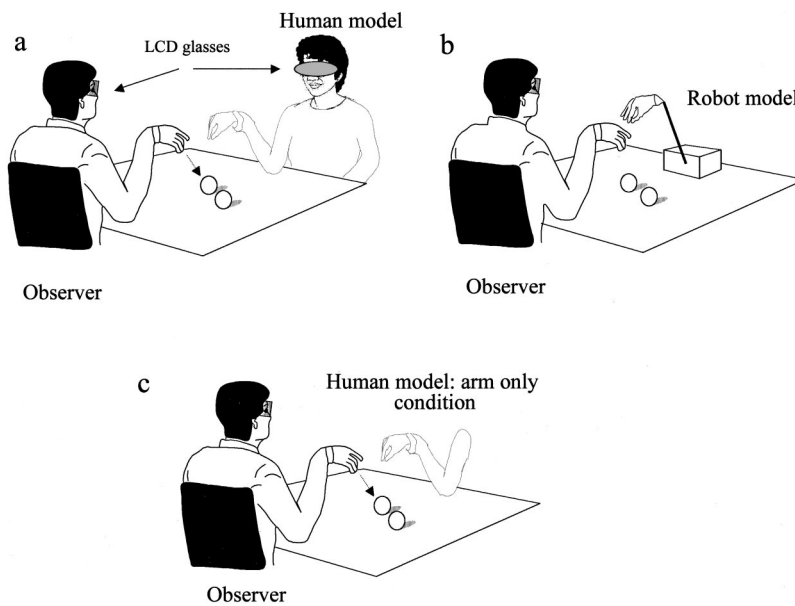


Figure 2. Schematic representation of the model-observer conditions for Experiment 1 (a and b) and Experiment 3 (c). Note that the distractor could be presented either to the left or to the right of the target, and it could be either the same size as the target, smaller than the target, or not present.





small distractor than it was in the presence of either the same-size distractor or no distractor (see Table 1).

*Models' deceleration time.* As revealed by the significance of the main variable type of distractor, deceleration time was longer for the small distractor condition than for either the same-size distractor condition or the no distractor condition (see Table 1).

*Models' amplitude of maximum grip aperture.* The results obtained for the maximum opening of the hand suggested that interference effects prevailed on movement parameterization. The significance of the main variable type of distractor revealed that the amplitude of maximum grip aperture did differ with respect to distractor type. The amplitude of the maximum grip aperture was smaller for the target presented either in combination with the same-size distractor or in isolation (see Table 1).

*Observers' movements.* For the observer group, the interaction Type of Model  $\times$  Type of Observed Trial was significant for various measures, as outlined subsequently. The observers' movements to the target varied with respect to whether they observed the human model grasping the target in the presence or in the absence of distractor stimuli. Of great interest is the unexpected presence of this effect in the human model condition during the catch trials, as this effect was not found for any of the dependent measures for both standard trials and catch trials when the robot was the model (see Figure 3 and Table 2). These latter results apply to all experiments reported herein (for the sake of brevity, they are not reported in the text; see Figure 3 and Table 2).

*Observers' movement duration.* For this parameter, the interaction Type of Model  $\times$  Type of Observed Trial was significant,  $F(1, 11) = 6.01, p < .05$  (see Table 2). For the observer, movement duration was longer when the action was performed after observing the human model grasping the target in the presence of the small distractor than in either the presence of the same-size distractor or the absence of a distractor ( $ps, < .05$ ; see Table 2). Similar effects were found for the catch trials in which the model did not move (see Figure 3).

*Observers' deceleration time.* For this parameter, the interaction Type of Model  $\times$  Type of Observed Trial was significant,  $F(1, 11) = 10.32, p < .001$  (see Table 2). Deceleration time was significantly longer when the action was performed after observing the human model grasping the target in the presence of the small distractor than in either the presence of the same-size distractor or the absence of a distractor. Similar effects were found for the catch trials (see Figure 3).

*Observers' amplitude of maximum grip aperture.* The results obtained for the maximum opening of the hand suggested that interference effects prevailed on movement parameterization. The interaction Type of Model  $\times$  Type of Observed Trial was significant,  $F(1, 11) = 5.01, p < .05$  (see Table 2). The amplitude of the maximum grip aperture was smaller when the action was performed after observing the human model grasping the target in the presence of the small distractor than in either the presence of the same-size distractor or the absence of a distractor. Similar effects were found for the catch trials (see Figure 3).

## Discussion

The results for the human model group confirmed that it is the implicit processing of the distractor that produces interference effects. In other words, the type of representation created for the

distractor contains information about action that competes with the action programmed for the target object (for a review, see Castiello, 1999). These interference effects provide the baseline measure necessary for the investigation of the action observation effects under scrutiny in this experiment. The transfer of interference effects from the human model to the observer indicates that features of the action performed by the human model were coded with respect to the presence or the absence of the distractor. The fact that I found interference effects for the observer action with the human but not with a robot model indicates that action priming was not due to participants preprogramming actions on the basis of the presence or absence of the distractor object. If this had been the case, the reported effects should have occurred for the robot primes as well as the human primes.

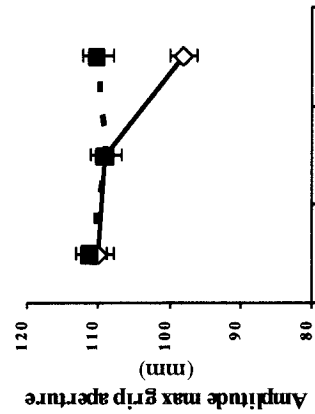
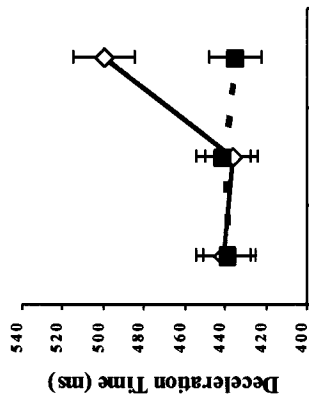
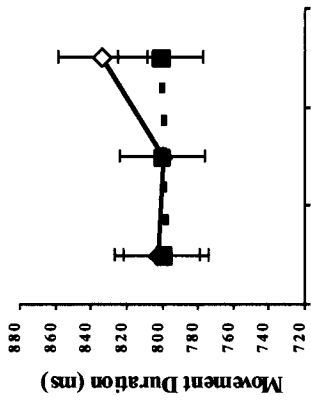
Of interest is the fact that these effects were also present when the catch trials were administered to the human model. This finding may suggest that when the kinematics of the model are not available, the model's motor intentions can be inferred by monitoring other visual cues presented by the model. Such cues would enable the observer to detect the motor intentions of the model. Such detection would automatically induce the observer to reenact the inferred action, as suggested by the interfering effect of the incongruent distractor on the observer's kinematics. The term *intention* is thus referred to here as the interfering effect due to the presence of the incongruent distractor being the unintentional result of the unconscious and automatic processing of its physical features. The natural questions are, therefore, these: What is the nature of these visual cues? And how do they allow for the translation of the gained information into motor schemas? The subsequent experiments aimed to provide an answer to the former question.

The lack of a catch trials effect in the robot condition might mean that the observer tried carefully to replicate the robotic movement. In this respect, replication of the robot's movement was as accurate as replication of the human model's movement (i.e., the robot did not vary its movement kinematics according to the presence or the absence of the distractor). Both the catch trials effect found for the human model and the lack of a catch trials effect for the robot model point to a carryover effect from those trials in which the models did move. However, the lack of a catch trials effect in the robot condition might also mean that the robotic model did not provide the observers with the necessary cues to trigger the catch trials effect. Experiment 2 was designed to clarify this issue.

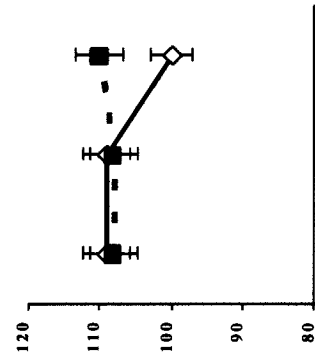
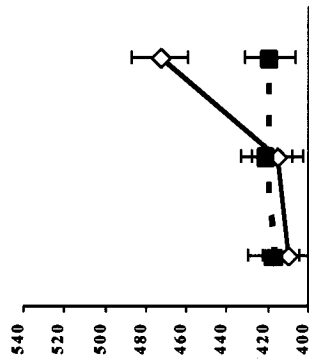
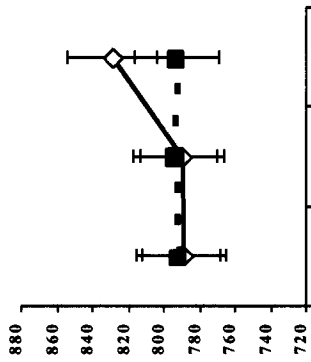
## Experiment 2

To further investigate the nature of the catch trials effect, I constrained the human models to perform the action toward the target as did the robotic arm—that is, in a similar way, irrespective of the presence or the absence of a distractor. Thus, if the catch trials effect is a carryover due to the “reading” of the kinematics of the action previously observed, a similar movement pattern for movements performed in the presence or the absence of a distractor should produce a similar noneffect for the human model condition. In contrast, if the catch trials effect is related to the ability of the observer to infer other cues from the model, which might be independent of either the kinematics or the visual display, differences in performance with respect to the standard trials and

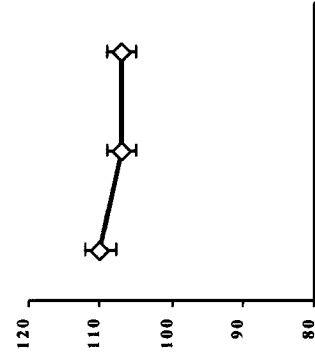
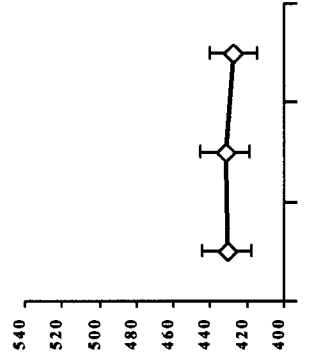
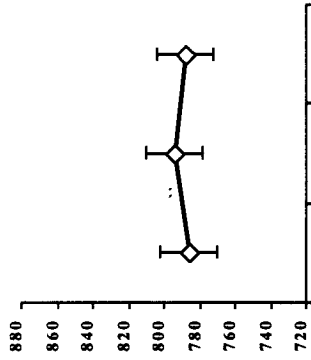
◇ ---◇ Human    ■ - - - ■ Robot



ND SS S  
Experiment 1



ND SS S  
Experiment 2



ND SS S  
Experiment 3

Table 2  
*Movement Durations, Deceleration Times, and Amplitude of Maximum Grip Apertures for Observers' Movements for No Distractor (ND), Same-Size Distractor (SS), and Small Distractor (S) Trials Following Observation of Human or Robot Models in Experiments 1–3*

Model type and variable	Experiment 1			Experiment 2			Experiment 3		
	ND	SS	S	ND	SS	S	ND	SS	S
<b>Human</b>									
Movement duration (ms)	800 (84)	812 (78)	863 (94)	786 (81)	798 (78)	801 (84)	784 (79)	782 (83)	854 (87)
Deceleration time (ms)	438 (45)	442 (46)	491 (54)	412 (43)	415 (43)	417 (48)	426 (45)	419 (43)	435 (47)
Amplitude maximum grip aperture (mm)	109 (3)	110 (2)	96 (3)	108 (1)	108 (2)	108 (3)	112 (3)	110 (3)	108 (2)
<b>Robot</b>									
Movement duration (ms)	804 (82)	805 (81)	799 (79)	791 (83)	793 (82)	793 (87)			
Deceleration time (ms)	441 (56)	439 (60)	444 (48)	421 (45)	418 (44)	428 (45)			
Amplitude maximum grip aperture (mm)	110 (2)	109 (2)	111 (2)	109 (2)	108 (1)	108 (3)			

Note. Standard deviations appear in parentheses.

the catch trials for both the human and the robot conditions should still be evident.

### Method

**Participants.** Twenty students (14 women and 6 men, ages 17–24 years) with the same characteristics as those who took part in Experiment 1 volunteered to participate. None of them had participated in the previous experiment. They attended one experimental session of ~1-hr duration. Half of the participants were randomly assigned to the model group, the other half to the observer group.

**Materials, apparatus, data processing, and procedure.** These were the same as those for Experiment 1, except that for this experiment a naive participant was asked to be the human model. The participants assigned to the model group were instructed to reach for the target object within an interval that corresponded to the time taken by the robotic hand to complete the same movement (800 ms  $\pm$  25 ms). The interval was defined by two sounds (200-ms sound duration; 880-Hz frequency). This led to the model using a movement pattern to the target that was very similar to that of the robot—that is, independent of the presence or the absence of a distractor.

### Results

Results obtained that pertain to the distractors' positions are not reported, given that no significant differences were found in any of the dependent measures.

**Models' movements.** Of relevance to the present study is the fact that the normalization procedure was successful. Kinematic analyses of the movements performed by the model showed that there were no differences for the dependent measures of interest as a function of the type of trial (see Table 1). That is, the classic kinematic patterning that characterizes the reach-to-grasp action

for large objects (i.e., the target) was not modified according to the classic kinematic pattern that characterizes smaller objects (i.e., the small distractor). Movement duration and deceleration time were not prolonged, and the amplitude of maximum grip aperture did not vary with respect to the target–distractor combination (see Table 1).

**Observers' movements.** For the observer group, the interaction Type of Model  $\times$  Type of Observed Trial was significant for movement duration,  $F(1, 9) = 12.31, p < .001$ ; deceleration time,  $F(1, 9) = 3.21, p < .05$ ; and the amplitude of maximum grip aperture,  $F(1, 9) = 4.84, p < .05$ . For the catch trials, but not for the standard trials, movement duration and deceleration were longer, and the amplitude of maximum grip aperture was smaller (see Table 2 and Figure 3). This pattern was found when the observers watched the human model observing the target in the presence of the small distractor but not in either the presence of the same-size distractor or the absence of a distractor.

### Discussion

The results from this experiment suggest that the transfer of interference effects, which were noticed only for the catch trials, reinforces the hypothesis that the human model provides cues that allow the transfer of motor intentions (as defined in the *Discussion* section under Experiment 1), which are independent of action execution. Why did the transfer of interference occur only for the catch trials and not for the standard trials? A possible answer is that the subtle intentional stage can be overridden by potent motor priming effects that are automatically triggered by the previously observed action.

Figure 3 (opposite). Movement durations, deceleration times, and amplitude of maximum (max) grip apertures for observers' movements after observing the models' catch trials in the no distractor (ND), same-size distractor (SS), and small distractor (S) trials in Experiments 1–3. Error bars represent standard errors.



The differences found between the human and the robot conditions for the catch trials provide some insight into the nature of the cues used by the observer to gain information about how an action is going to be executed when no overt motor action has been demonstrated. In Experiment 1, more body information was available from the human model than from the robot model, and this additional information may have provided the cues necessary to influence observers' performance, even for the catch trials. In this respect, Perrett et al. (1989) found effects due to sight of action when the entire body and face of the experimenter performing the action were visible. When only the hand of the experimenter was visible, cells were much less responsive. The aim of the following experiment was to test the hypothesis that the limited amount of body information available to the observer could be the determinant for the appearance of the catch trials effect.

### Experiment 3

In Experiment 3, I investigated whether the catch trials effect is related to the amount of body information available to the observer. To this end, for the human model, only the forearm and the hand were visible.

#### Method

*Participants.* Sixteen students (10 women and 6 men, ages 18–25 years) with the same characteristics as those who took part in the previous experiments volunteered to participate. None of them had participated in the previous experiments. They attended one experimental session of ~1-hr duration. Half of the participants were randomly assigned to the observer group, the other half to the model group.

*Materials, apparatus, data processing, and procedure.* These were the same as those for Experiment 1, except for two major modifications. First, in the present experiment no robot conditions were considered, and, second, only the arm of the human model was visible to the observer. The face and the body of the human model were hidden behind a screen (see Figure 2c).

#### Results

Kinematic analyses showed that, for the model group, there were differences between movements directed to the target in the presence and in the absence of a distractor (see Table 1). For the observer group, the lack of face and body information did bring about a noticeable reduction in transfer interference for both the catch trials and the standard trials (see Table 2 and Figure 3). For the observer group, the main variable type of observed trial was significant only for movement duration during the standard trials,  $F(1, 7) = 10.54, p < .001$  (see Table 2). Deceleration time and the amplitude of maximum grip aperture approached significance for the standard trials,  $p < .058$  and  $p < .055$ , respectively (see Figure 3), but no catch trials effect was found. Results pertaining to the distractors' positions are not reported, given that no significant differences were found in any of the dependent measures.

#### Discussion

The data from Experiment 3 confirmed that the catch trials effect is dependent on observers seeing more than just the arm of a human model. The effect was not obtained from the sight of a human arm disjointed from the body or the face of the person

reaching for and grasping an object. It appears that bodily or facial cues are necessary to allow for the catch trials effect.

Several authors have investigated the responsiveness of cells in the STS of macaque monkeys to head movements, eye gaze, and moving body parts (Hasselmo, Rolls, & Baylis, 1989; Oram & Perrett, 1996; Perrett et al., 1990; Rolls, Baylis, Hasselmo, & Nalwa, 1989). Similarly in humans, it was found that long-latency event-related potentials were generated in or near the STS in response to faces and to gaze direction (Puce et al., 1998).

The weight of the evidence provided so far suggests that the results for Experiment 3 highlight the importance of face and body expressions for the interpretation of early stages of actual, or implied, bodily movements and related cues. This observation, together with the fact that in this experiment the effect for the catch trials was absent, indicates that body and face movements may be the relevant cues for perceiving the motor disposition and intentions of other individuals (i.e., models). This issue is explored further in Experiment 4.

### Experiment 4

In Experiment 4, I asked the human model to perform the reach-to-grasp action toward the target either with the face hidden but the upper part of the body visible or with the face visible but the upper part of the body hidden. If some characteristics of the face (gaze direction, facial expression, etc.) are necessary cues for perceiving the motor disposition and intentions of other individuals, the catch trials effect should be evident only for the condition in which the model's face is visible, not for the condition in which the model's face is hidden.

#### Method

*Participants.* Twenty students (15 women and 5 men, ages 18–31 years) with the same characteristics as those who took part in the previous experiments volunteered to participate. None of them had participated in the previous experiments. They attended one experimental session of ~1-hr duration. Half of the participants were randomly assigned to the observer group, the other half to the model group.

*Materials, apparatus, data processing, and procedure.* These were similar to those used for Experiment 3, with the exception that there were two experimental conditions. In Condition A, the face of the human model was hidden behind a panel constructed from a thin black net material, but the upper part of the body was still visible (see Figure 4a). In Condition B, the face of the human model was visible, but the upper part of the body was hidden behind a similarly constructed panel (see Figure 4b). For the observers, the various dependent measures were analyzed by comparing Condition A with Condition B. The variables were thus condition (Condition A or Condition B) and type of observed trial (standard trials–no distractor, standard trials–same-size distractor, standard trials–small distractor, catch trials–no distractor, catch trials–same-size distractor, or catch trials–small distractor).

#### Results

Results pertaining to the distractors' positions are not reported, given that no significant differences were found in any of the dependent measures. As for Experiment 3, kinematic analyses showed that, for the model group, there were differences between movements directed to the target in the presence and in the absence of a distractor (see Table 1). For the observer group, the interaction

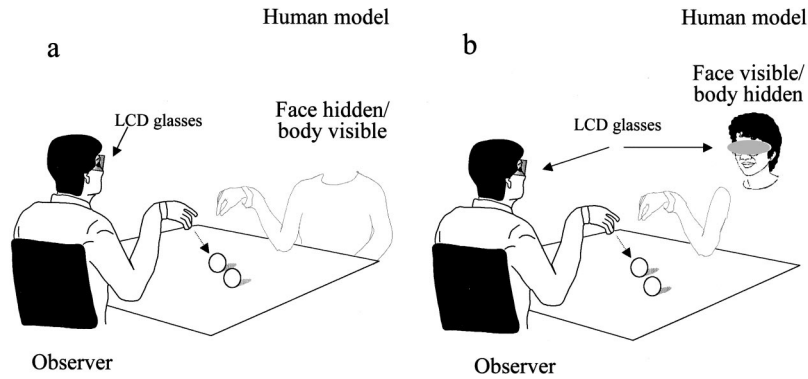


Figure 4. Schematic representation of the model-observer conditions for Condition A (a) and Condition B (b) for Experiment 4. Note that the distractor could be presented either to the left or to the right of the target, and it could be either the same size as the target, smaller than the target, or not present.

Condition  $\times$  Type of Observed Trial was significant for movement duration,  $F(1, 9) = 6.01, p < .05$ ; deceleration time,  $F(1, 9) = 13.21, p < .001$ ; and the amplitude of maximum grip aperture,  $F(1, 9) = 4.42, p < .05$ . For both the standard and the catch trials, in Condition B (in which the face was visible), movement duration and deceleration time were longer and the amplitude of maximum grip aperture was smaller when the small distractor, rather than the large or the no distractor, conditions was presented (see Table 3). No such effect was found for the catch trials in which the model's face was covered (i.e., Condition A).

Discussion

The results of Experiment 4 revealed that face cues are more relevant than upper body cues to obtainment of the catch trials effect. It is well established that observers glean considerable information from faces, and there is evidence to suggest that faces are processed in a relatively domain-specific fashion by neocortical sectors of the temporal lobe (Puce et al., 1998).

Gaze direction appears to be particularly relevant in guiding interactions with other humans (Kleinke, 1986). Sensitivity to gaze direction occurs early in human development. At 3 months of age,

children can detect in others the direction of perceived gaze, which in turn influences their own direction of attention (Hood, Willen, & Driver, 1998; Vecera & Johnson, 1995). In monkeys, gaze direction is an important component of facial expression. Perrett and colleagues have studied the responsiveness of monkey STS cells to both gaze and head direction. In general, they found that cell activation was greatest when the observer monkey viewed the model's full face while the model's gaze was averted, but some of the cells studied showed independent sensitivity to head and eye direction. In other words, these cells seemed to be concerned with the direction of another individual's attention (Hietanen, 2002; Perrett et al., 1990; Perrett, Hietanen, Oram, & Benson, 1992). In line with these findings, the results of the present experiment suggest that for the catch trials effect to be demonstrated, the observer requires an unrestricted view of the model's head and, by implication, gaze direction. The effect found for the catch trials may be a result of the amount of attention that the model pays to the target-distractor configuration, even though he or she does not move—this being detected by the observer through head movements and eye gaze. However, it must be said that, as Perrett et al. (1990, 1992) have pointed out, in many situations the direction in which another person's head is pointing is not a good index of where that person's attention lies. Gaze direction seems to be a much better guide to the focus of another's attention. Thus, it might be that it is through eye gaze that interference transfer takes place. In this view, interference transfer may be the result of the importance that the observer accords to the model's allocation of attention to task-relevant stimuli. Experiment 5 was designed to explore further the role of eye gaze in determining the effects revealed in the previous experiments.

Table 3  
Movement Durations, Deceleration Times, and Amplitude of Maximum Grip Apertures for Observers' Movements for the Body Visible-Face Hidden and Body Hidden-Face Visible Conditions in Experiment 4

Variable	Body visible-face hidden			Body hidden-face visible		
	ND	SS	S	ND	SS	S
Movement duration (ms)	823 (79)	831 (86)	842 (83)	843 (93)	878 (85)	901 (96)
Deceleration time (ms)	464 (53)	467 (60)	467 (58)	500 (49)	531 (56)	556 (58)
Amplitude of maximum grip aperture (mm)	110 (2)	110 (2)	109 (3)	109 (3)	107 (4)	96 (2)

Note. Standard deviations appear in parentheses. ND = no distractor; SS = same-size distractor; S = small distractor.

Experiment 5

In Experiment 5, I asked the model to perform the reach-to-grasp movement with either free or constrained vision; in the one case, the model was allowed to gaze about freely, whereas in the other, the model was asked to fixate on the target. In both instances, the other parts of the model's body were visible to the observer. If eye gaze is important in revealing the catch trials effect, in a condition in which the eyes are stationary no such effect should be found.

## Method

**Participants.** Twelve students (8 women and 4 men, ages 22–30 years) with the same characteristics as those who took part in the previous experiments volunteered to participate. None of them had participated in the previous experiments. They attended one experimental session of ~1-hr duration. Half of the participants were randomly assigned to the observer group, the other half to the model group.

**Materials, apparatus, data processing, and procedure.** These were similar to those used for Experiment 4, with the exception that the two experimental conditions were as follows: In Condition A, the model was allowed to gaze about freely; in Condition B, the model was required to maintain a steady gaze on the target. The order of the conditions was counterbalanced between the observers, who remained unaware of the type of condition being administered. An Applied Science Laboratories (Bedford, MA) eye movement recording system was used to detect all of the models' eye movements. The observers' eye movements were videotaped. The models' and the observers' eyes were monitored in the fixated condition as well as in the eyes moving condition. Independent judges affiliated with the University of Melbourne and Royal Holloway analyzed both the videotape recordings and the eye-tracking data. The statistical analysis included the main variable condition (Condition A or Condition B) and type of observed trial (standard trials–no distractor, standard trials–same-size distractor, standard trials–small distractor, catch trials–no distractor, catch trials–same-size distractor, or catch trials–small distractor).

## Results

Results pertaining to the distractors' positions are not reported, given that no significant differences were found in any of the dependent measures. Results for the model group were similar to those obtained for the previous experiments in which interference effects were found (see Table 1). No significant Condition  $\times$  Type of Observed Trial interactions were found. Thus, in Table 1 the data from the two conditions are merged.

**Observers' movements.** The interaction Condition  $\times$  Type of Observed Trial was significant for movement duration,  $F(1, 5) = 11.61, p < .001$ ; deceleration time  $F(1, 5) = 22.12, p < .0001$ ; and the amplitude of maximum grip aperture,  $F(1, 5) = 10.22, p < .001$ . For the condition in which the eyes moved freely, movement duration and deceleration time were longer and the amplitude of maximum grip aperture was smaller when the target was presented with the small distractor rather than the same-size distractor or no distractor (see Table 4). Similar effects were found for both the standard and the catch trials. When the models' eyes were stationary, no such effect (i.e., catch trials effect) was found (see Figure 5).

**Frequency of fixation on distractor during catch trials.** The analysis performed on the videotape recording (observer) and the eye-tracking data (model) allowed values for the number of times the model and the observer looked at both the target and the distractor during the standard and the catch trials before the observer performed the action to be established. Occurrences of these target–distractor scans were analyzed with respect to the type of trial and the experimental conditions. An analysis of variance with type of participant (model or observer) and type of observed trial (standard trials–no distractor, standard trials–same-size distractor, standard trials–small distractor, catch trials–no distractor, catch trials–same-size distractor, or catch trials–small distractor) as the main variables was carried out on the percentage of target–distractor scans performed by the model and by the observer to

Table 4  
*Movement Durations, Deceleration Times, and Amplitude of Maximum Grip Apertures for Observers' Movements for the No Eye Movements and Eye Movements Conditions in Experiment 5*

Variable	No eye movements			Eye movements		
	ND	SS	S	ND	SS	S
Movement duration (ms)	795 (69)	807 (99)	812 (89)	818 (77)	822 (79)	854 (92)
Deceleration time (ms)	421 (58)	427 (69)	431 (75)	432 (49)	441 (53)	465 (43)
Amplitude of maximum grip aperture (mm)	107 (1)	110 (3)	108 (3)	110 (2)	109 (3)	101 (2)

*Note.* Standard deviations appear in parentheses. ND = no distractor; SS = same-size distractor; S = small distractor.

both the target and the distractor during the standard and the catch trials. The percentage was calculated with respect to the total number of trials in which the distractor was present for both the standard and the catch trials for Condition A. No significant differences were found with respect to participant type. Both the model and the observer oriented their eyes toward the target and then the distractor (or vice versa) a similar number of times (model: 96%; observer: 94%) and independently of the type of trial. In contrast, the main effect type of observed trial was significant,  $F(1, 5) = 21.96, p < .001$ . For both the catch and the standard trials, 98% of eye movements were concerned mainly with the target position. Furthermore, the percentage of target–distractor eye scans was significantly greater for the catch trials–distractor conditions (small: 97%; same size: 96%) than for the standard trials–distractor conditions (small: 93%; same size: 92%). A further analysis was carried out to correlate the gaze direction of the models with the observers' direction of gaze. This analysis was conducted separately for the standard ( $r = .56$ ) and the catch ( $r = .78$ ) trials, with a high level of correlation being found. This analysis demonstrated that the model and the observer looked toward roughly the same location before and during both the standard and the catch trials. Unfortunately, given the limitations of the eye movement analysis conducted on the observers (videotape recording), it has not been possible to look at the temporal aspects of these data—for example, whether the eyes of the observer follow the eyes of the model or vice versa.

## Discussion

The results of Experiment 5 highlighted the importance of a sophisticated behavior such as the ability to follow and use gaze-direction information (Emery, Lorincz, Perrett, Oram, & Baker, 1997), which demonstrated that both the model and the observer tended to fixate on the two objects during both the standard and the catch trials. These findings are in agreement with previous research by Mataric and Pomplun (1998) in which subjects were shown videotapes of different types of natural but unfamiliar finger, hand, and arm movements that they were told either to imitate or just watch. Mataric and Pomplun's data showed that humans derive the specification of a movement task largely by locating the stimulus end point.

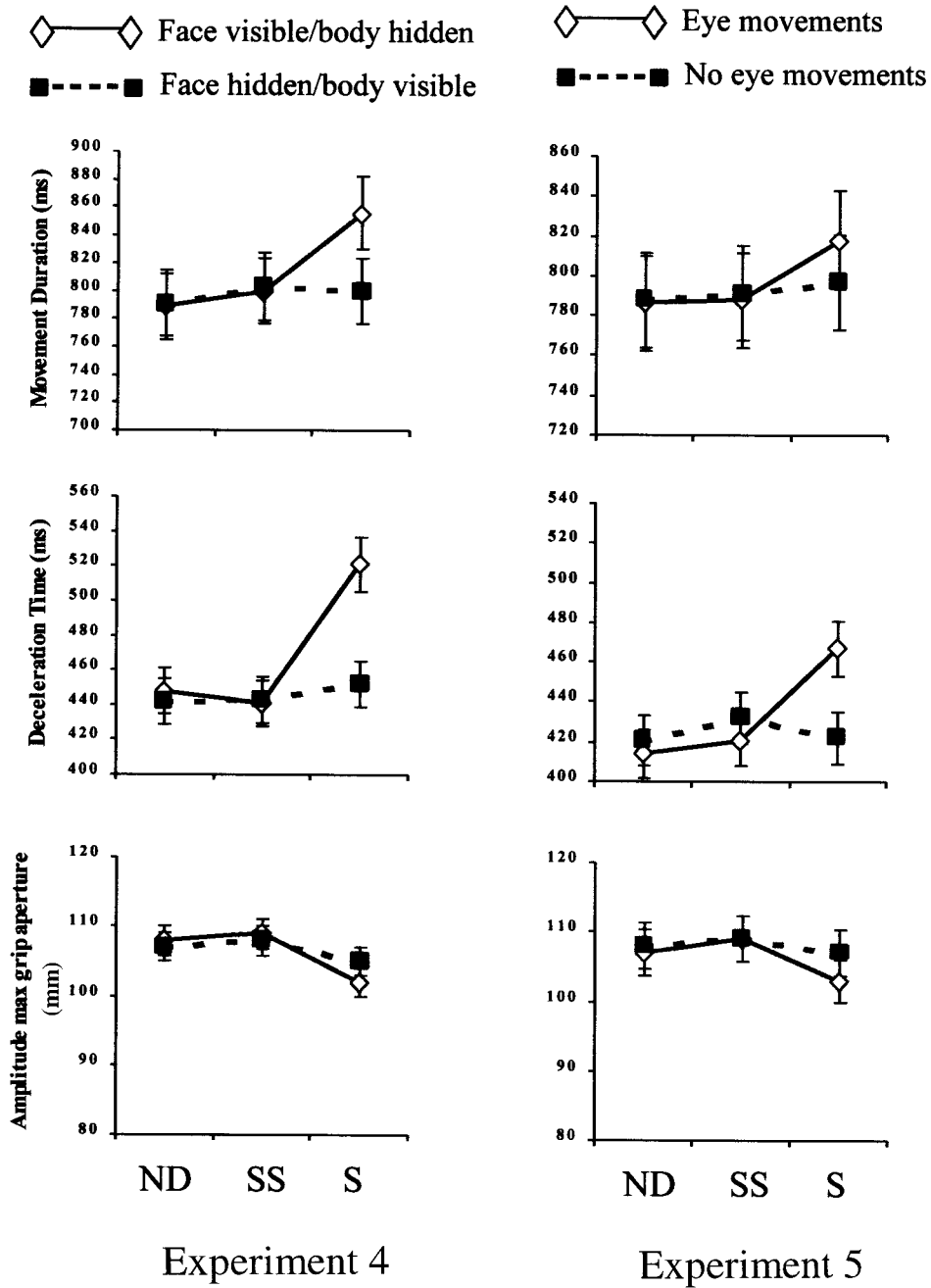


Figure 5. Movement durations, deceleration times, and amplitude of maximum (max) grip apertures for observers' movements after observing the models' catch trials in the no distractor (ND), same-size distractor (SS), and small distractor (S) trials in Experiments 4 and 5. Error bars represent standard errors.

Further support for the present data comes from the field of neurophysiology, specifically Jellema et al.'s (2000) description of a population of cells in the STS area of the macaque monkey that respond to the observation of reaching movements performed with the arm in a specific direction. The responses of a subset of these cells were affected by the gaze direction of the model performing the reaching action. It is interesting to note that Jellema et al. also found that information about the reaching action, such as its

direction and the possible presence of a reaching goal, was linked to information about the direction of overt attention of the performer. In other words, the cells were selective for actions when the attention of the model was focused on the goal of the action. Similarly, in the present research I found that both the standard and the catch trials effects were evident in the observer only when the model was allowed to orient overtly toward the stimuli. This may mean that information from another person's gaze direction is

integrated with centers devoted to the planning and execution of arm movements. A further point of consideration is the fact that the model was affected by the distractor even though he or she was not allowed to attend to it. However, it is well-known that stimuli in the visual field can be attended covertly—that is, without explicit movement of the body or the eyes (Posner, 1980). Furthermore, it has been demonstrated that distractor objects that are covertly attended can influence the reach-to-grasp action toward a target (Bonfiglioli & Castiello, 1998).

### General Discussion

The basic goal of this study was to achieve a better understanding of the mechanisms that underlie the action observation–execution matching system recently described in monkeys and humans (Fadiga et al., 1995; Gallese et al., 1996). First and foremost, the findings in this article indicate that perception of the movement of the eyes of models provides information about models' actions and intentions without the necessity that they perform an actual movement. But how does this priming from another's eye direction occur? It is possible that, during the catch trials, the observer recognized the pattern of the model's gaze direction as similar to that showed by the model during the standard trials, in which it was associated with the reaching action. Consequently, in the catch trials, in which the kinematics of the model were not available, the observer, by monitoring gaze direction, inferred and retrieved from previous experience the motor intentions of the model. Such a detection–recognition–retrieval process would automatically induce the observer to reenact the inferred action, as suggested by the interfering effect of the incongruent distractor on the observer's kinematics. If this postulation is correct, it might be expected that this behavioral effect would be underpinned by some specialized neural circuitry tailored to perceive another's eyes and the direction in which he or she is gazing and to link this information with motor action.

In the introduction, I discussed how F5 neurons are invoked as one of the possible neural mechanisms subtending the mirror system in both humans and monkeys. Here, the possible activation of F5 neurons makes sense only for the standard trials, in which the observer was witnessing the perturbed kinematics displayed by the human model; it is difficult to invoke F5 neurons in the case of the catch trials, in which no reach-to-grasp action was observed. Thus, the effect is possibly driven by a neural mechanism that is able to translate the observation of eye movement directed toward the target and the distractor, alternatively, into the corresponding motor schemas required to interact with both objects. The result would be a conflict that would produce the interference effect. The suggestion here is that there is a strong association between eye direction and subsequent arm–hand movements. A possible neural circuit in which the integration of eye gaze and hand information takes place is discussed in a recent neuroimaging study by Hoffman and Haxby (2000; see also Harries & Perrett, 1991). These authors found that the representation of eye gaze depends on the activity in the STS and that selective attention to gaze direction elicits activity within the intraparietal sulcus (IPS), an area that has been shown to be important for the visual control of action (Milner & Goodale, 1995). For instance, neurons matching the structure of an object with grasping movements directed toward the object have been found in the lateral bank of the IPS (Sakata & Taira,

1994). The catch trials effect found in the present study might be the result of STS and IPS activity elicited in the observer by the interpretation of the eye gaze from the model. The model's eye gaze brings the attention of the observer to the two objects, and the information is then channeled from the STS to the IPS system, which in turn has to work harder to process the target and distractor object information in terms of the possible grasping actions the objects permit. Then, when the observer has to perform the action, traces of the motor parallel processing triggered by the model's eye gaze for the two objects is reflected in the observer's subsequent action. The result is the interference effect also noted for the catch trials.

The high degree of correlation between the models' and observers' directions of gaze suggests that a role is played by joint-attention mechanisms in the modulation of the catch trials effect. Related findings support the assumption that there is a differential level of significance, depending on whether someone reaches toward an object with his or her attention directed toward that object or with attention directed elsewhere. The interesting proposal here is that it is the direction of attention that modulates the responses of the reaching cells, such that the response magnitude of these cells reflects the intentionality of the action (Jellema et al., 2000). Similarly, I found the catch trials effect only when the model was free to overtly orient attention toward the target and the distractor. The model's movement of overt attention from one object to the other enhances in the observer possible responses to both objects, thus modulating the subsequent reaching action, even though this action is performed toward only one object. It can therefore be suggested that this sharing of attention based on gaze monitoring is at the base of the coding of motor intention (as defined here). It is not unusual to try to get someone to do something just by catching his or her eyes and directing his or her attention toward a salient object, without moving either the head or the hands or even producing any vocalization. These systems may thus be considered sophisticated systems involved in the implicit processing of motor information. In other words, the unintentional motor patterning exhibited by the observer may be formed on the basis of the direction of attention of the model performing the previously observed action.

One issue of interest in the present study is the investigation of a possible categorical difference between the biological movement of the human model and the mechanical movement of the robot. On the basis of previous evidence that revealed differential activation of the action observation–execution matching system with nonbiological models, it was predicted that the movement of the observer would have been differently affected by the robot prime (Gallese et al., 1996; Perrett et al., 1990). However, despite the fact that the observers were not informed that the movement of the robotic arm was similar for the no distractor and the distractor conditions, they replicated the robot movement and discounted the presence of the distractor object. This finding suggests that the kinematics of the movement primed the action, irrespective of whether the kinematics were demonstrated by a human or a robot model. The results of the catch trials for the robot condition confirm those for the standard trials, in the sense that if the movement of the robot is not influenced by the distractor, replicating its intentions yields the same lack of distractor effect. However, the presence of the catch trials effect and the lack of transfer of interference effect for the standard trials for the human



condition in Experiments 2 and 3, in which the human models performed the action similarly to the robot, point to possible categorical differences between the human and the robot models. Thus, the comparison between the human and the robotic models has proved to be important for the exploration and the identification of the cues necessary to identify the nature of the catch trials effect found for the human condition. Nevertheless, understanding of the extent to which such effects may be due to a specialization of the action observation–execution matching system for biological action and the nature of the relevant cues sent by the model will require further experimentation.

As a final point, the evidence that the kinematic coding of an action viewed by the observer influences the action subsequently performed by the observer appears to confirm a strict link between the perceptual and the motor systems. This conclusion is in line with Meltzoff and Moore's (1977) work, which proposes that such a link enables young children to implicitly imitate facial and hand movements without visual feedback. Further, the data I describe here may also be complementary with recent work that has applied stimulus–response compatibility to action imitation. In particular, it has been demonstrated that movement observation influences subsequent movement execution, even for a task for which the response is predefined. This finding strongly supports the assumption of automaticity, in the sense that this priming process occurs involuntarily and is not under the model's control (Brass, Bekkering, & Prinz, 2001; Stürmer, Aschersleben, & Prinz, 2000). In this respect, nonintentional imitation of action is a special case of stimulus–response compatibility, such that the stimulus prespecifies certain aspects of the perceivable consequences of action (Brass et al., 2001).

In conclusion, this study identifies new conditions for understanding the link between action perception and execution. It suggests that, even in the absence of any overtly executed action, observers can still read other people's motor intentions (as defined here), provided they can see a model's face, in particular his or her gaze direction. However, when the kinematics are available, motor intentions can be overridden by potent motor priming effects.

## References

- Baron-Cohen, S., Campbell, R., Karmiloff-Smith, A., Grant, J., & Walker, J. (1995). Are children with autism blind to the mentalistic significance of the eyes? *British Journal of Developmental Psychology*, *13*, 379–398.
- Bonfiglioli, C., & Castiello, U. (1998). Dissociation of covert and overt spatial attention during prehension movements: Selective interference effects. *Perception & Psychophysics*, *60*, 1426–1440.
- Brass, M., Bekkering, H., & Prinz, W. (2001). Movement observation affects movement execution in a simple response task. *Acta Psychologica*, *106*, 3–22.
- Butterworth, G. (1990). On reconceptualizing sensorimotor coordination in dynamic system terms. In H. Bloch & B. I. Berenthal (Eds.), *Sensory motor organizations and development in infancy and early childhood* (pp. 57–73). Dordrecht, the Netherlands: Kluwer Academic.
- Castiello, U. (1996). Grasping a fruit: Selection for action. *Journal of Experimental Psychology: Human Perception and Performance*, *22*, 582–603.
- Castiello, U. (1999). Mechanisms of selection for the control of hand action. *Trends in Cognitive Science*, *7*, 264–271.
- Castiello, U., Lusher, D., Mari, M., Edwards, M., & Humphreys, G. (2002). Observing a human or a robotic hand grasping an object: Differential motor priming effects. In W. Prinz & B. Hommel (Eds.), *Common mechanisms in perception and action: Attention and performance XIX* (pp. 315–333). New York: Oxford University Press.
- Decety, J., Perani, D., Jeannerod, M., Bettinardi, V., Tardary, B., Woods, R., et al. (1994, October 13). Mapping motor representations with positron emission tomography. *Nature*, *371*, 600–602.
- Emery, N. J., Lorincz, E. N., Perrett, D. I., Oram, M. W., & Baker, C. I. (1997). Gaze following and joint attention in rhesus monkeys (*Macaca mulatta*). *Journal of Comparative Psychology*, *111*, 286–293.
- Fadiga, L., Fogassi, L., Pavesi, G., & Rizzolatti, G. (1995). Motor facilitation during action observation: A magnetic stimulation study. *Journal of Neurophysiology*, *73*, 2608–2611.
- Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain*, *119*, 593–609.
- Grafton, S. T., Arbib, M. A., Fadiga, L., & Rizzolatti, G. (1996). Localization of grasp representations in humans by positron emission tomography: 2. Observation compared with imagination. *Experimental Brain Research*, *112*, 103–111.
- Greenwald, A. G. (1970). A choice reaction time test of ideomotor theory. *Journal of Experimental Psychology*, *94*, 52–57.
- Harries, M. H., & Perrett, D. I. (1991). Visual processing of faces in the temporal cortex: Physiological evidence for a modular organization and possible anatomical correlates. *Journal of Cognitive Neuroscience*, *3*, 9–24.
- Hasselmo, M., Rolls, E., & Baylis, G. (1989). The role of expression and identity in the face-selective responses of neurons in the temporal visual cortex of the monkey. *Behavioural Brain Research*, *32*, 203–218.
- Heyes, C. (2001). Causes and consequences of imitation. *Trends in Cognitive Science*, *5*, 253–261.
- Hietanen, J. K. (2002). Social attention orienting integrates visual information from head and body orientation. *Psychological Research*, *66*, 174–179.
- Hoffman, E. A., & Haxby, J. V. (2000). Distinct representation of eye gaze and identity in the distributed human neural system for face perception. *Nature Neuroscience*, *3*, 80–84.
- Hood, B. M., Willen, J., & Driver, J. (1998). Adult's eyes trigger shifts of visual attention in human infants. *Psychological Science*, *9*, 131–134.
- Jakobson, L. S., & Goodale, M. A. (1991). Factors affecting higher-order movement planning: A kinematic analysis of human prehension. *Experimental Brain Research*, *86*, 199–208.
- James, W. (1890). *The principles of psychology* (Vols. 1 & 2). New York: Holt.
- Jellema, T., Baker, C., Wicker, B., & Perrett, D. I. (2000). Neural representation for the perception of the intentionality of actions. *Brain Cognition*, *44*, 280–302.
- Kleinke, C. (1986). Gaze and eye contact: A research review. *Psychological Bulletin*, *100*, 78–100.
- Mataric, M. J., & Pomplun, M. (1998). Fixation behavior in observation and limitation of human movement. *Cognitive Brain Research*, *7*, 191–202.
- Meltzoff, A. N. (1995). Understanding of the intentions of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology*, *31*, 838–850.
- Meltzoff, A. N., & Moore, M. K. (1977, October 7). Imitation of facial and manual gestures by human neonates. *Science*, *198*, 75–78.
- Milner, A. D., & Goodale, M. (1995). *The visual brain in action*. Oxford, England: Oxford University Press.
- Oram, M. W., & Perrett, D. I. (1996). Integration of form and motion in the anterior superior polysensory area (STPa) of the macaque monkey. *Journal of Neurophysiology*, *76*, 109–129.
- Perrett, D. I., Harries, M. H., Bevan, R., & Thomas, S. (1989). Frameworks of analysis for the neural representation of animate objects and actions. *Journal of Experimental Biology*, *146*, 87–113.
- Perrett, D. I., Harries, M. H., Mistlin, A. J., Hietanen, J. K., Benson, P. J., Bevan, R., et al. (1990). Social signals analysed at the single cell level:

- Someone is looking at me, something touched me, something moved! *International Journal of Comparative Psychology*, 4, 25–55.
- Perrett, D., Hietanen, J., Oram, M., & Benson, P. (1992). Organization and functions of cells responsive to faces in the temporal cortex. *Philosophical Transactions: Biological Sciences*, 335, 23–30.
- Perrett, D. I., Rolls, E. T., & Caan, W. (1982). Visual neurons responsive to faces in the monkey temporal cortex. *Experimental Brain Research*, 47, 329–342.
- Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, 32, 3–25.
- Prinz, W. (1987). Ideomotor action. In H. Heuer & A. F. Sanders (Eds.), *Perspectives on perception and action* (pp. 47–76). Hillsdale, NJ: Erlbaum.
- Puce, A., Allison, T., Bentin, S., Gore, J., & McCarthy, G. (1998). Temporal cortex activation in humans viewing eye and mouth movements. *Journal of Neuroscience*, 18, 2188–2199.
- Rizzolatti, G., & Arbib, M. (1998). Language within our grasp. *Trends in Neurosciences*, 21, 188–194.
- Rizzolatti, G., Fadiga, L., Gallese, V., & Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. *Cognitive Brain Research*, 3, 131–141.
- Rizzolatti, G., Fadiga, L., Matelli, M., Bettinardi, V., Perani, D., & Fazio, F. (1996). Localization of cortical areas responsive to the observation of hand grasping movements in humans: A PET study. *Experimental Brain Research*, 111, 246–256.
- Rolls, E., Baylis, G., Hasselmo, M., & Nalwa, V. (1989). The effect of learning on the face selective responses of neurons in the cortex in the superior temporal sulcus of the monkey. *Experimental Brain Research*, 76, 153–164.
- Sakata, H., & Taira, M. (1994). Parietal control of hand action. *Current Opinion in Neurobiology*, 4, 847–856.
- Stürmer, B., Aschersleben, G., & Prinz, W. (2000). Correspondence effects with manual gestures and postures: A study of imitation. *Journal of Experimental Psychology: Human Perception and Performance*, 26, 1746–1759.
- Umiltá, M. A., Kohler, E., Gallese, V., Fogassi, L., Fadiga, L., Keysers, C., & Rizzolatti, G. (2001). I know what you are doing: A neurophysiological study. *Neuron*, 31, 155–165.
- Vecera, S., & Johnson, M. (1995). Gaze detection and the cortical processing of faces: Evidence from infants and adults. *Visual Cognition*, 2, 59–87.
- Wicker, B., Michel, F., Henaff, M.-A., & Decety, J. (1998). Brain regions involved in the perception of gaze: A PET study. *NeuroImage*, 8, 221–227.
- Woodward, A. L. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition*, 69, 1–34.

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