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Observational learning without a model is influenced by the observer's possibility to act: Evidence from the Simon task

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ABSTRACT

We assessed whether observational learning in perceptual-motor tasks is affected by the visibility of an action producing perceived environmental effects and by the observer's possibility to act during observation. To this end, we conducted three experiments in which participants were required to observe a spatial compatibility task in which only the effects of computer-generated responses were visible before executing a Simon task. In Experiment 1, we compared the effects of a passively observed practice with either a spatially compatible or incompatible stimulus–response (S–R) association. In Experiment 2, during the observed spatially incompatible practice participants were prevented from potentially acting, either because a plexiglas barrier separated the participant from the response device rendering it out of reach; or because the participant's hands were tied; or the device affording a response was absent. In Experiment 3, the plexiglas presented an opening that could allow the participant to potentially reach and interact with it. As when the practice is physically performed, we found an elimination of the Simon effect following a spatially incompatible observed practice, suggesting that participants learned an incompatible S–R association by observing and transferred this knowledge to the subsequent Simon task. No evidence of transfer of learning was found when, during passive observation, the participant's hands were tied, or a barrier prevented him/her from potentially interacting with the device, or no response device was present. Differently, a transfer-of-learning effect was observed when the barrier presented an opening. These results suggest that learning can derive from the mere observation of action effects, even when an action is not visible, as long as the observer has the potential to act.

1. Introduction

Observing the actions of others can influence our behaviors in several ways. As regards perceptual-motor performance, it has been widely demonstrated that observing the actions of others facilitates the execution of the same actions by the observer (e.g., Brass, Bekkering, & Prinz, 2001). From a cognitive point of view, this effect may be explained by invoking an influential account of action control, the Ideomotor account (James, 1890; Prinz, 1997), which proposes a common representational basis for perception and action (Hommel, Müsseler, Aschersleben, & Prinz, 2001). According to this view, actions are cognitively represented in terms of their response effects. Through repeated experience, actions and response effects that derive from these actions become associated. As a consequence of this, when individuals perceive events and they know, from previous experience, that they may

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result from certain movements, perception of these events may evoke the movements causing them (e.g., Elsner & Hommel, 2001). For instance, in Elsner and Hommel's study participants were required to go through an acquisition session, in which a left or right keypress response was always followed by a particular tone (e.g., a left keypress was always followed by an high-pitch tone, while a right keypress was always followed by a low-pitch tone). In a second session, the same tones were used as stimuli for a two-choice response. They found that response times in the second session were faster when a keypress was performed in response to the tone that had previously been associated to it as compared to when it was performed to a tone that had been previously associated to the alternative response. This result was taken as evidence that, during the acquisition session, participants acquired bidirectional associations between the motor code of the action and the perceptual code of the effect (i.e., an action-effect association). Consequently, when the effect (the tone) was presented as an imperative stimulus in the second session, the associated action was activated, speeding up or slowing down performance depending on whether the activated action and the required response were compatible or incompatible with the instructed response.

From a neurophysiological point of view, accumulating evidence suggests that the observation of another individual acting activates a ‘‘mirror mechanism’’ (e.g., Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Gallese, Gernsbacher, Heyes, Hickock, & Iacoboni, 2011; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996), that simulates under threshold the perceived action leading to motor facilitation for imitative behavior, as long as the actions belong to the observer's repertoire (e.g., Calvo-Merino, Glaser, Grezes, Passingham, & Haggard, 2005; Calvo-Merino, Grèzes, Glaser, Passingham, & Haggard, 2006; but see Cross et al., 2012 for different results). This activation is thought to allow the observer to rapidly understand the other person's actions and their consequences (Gallese & Sinigaglia, 2011b; Rizzolatti & Sinigaglia, 2010) and to support observation learning (e.g., Iacoboni et al., 1999; Mattar & Gribble, 2005).

The study by Elsner and Hommel (2001) showed that action-effect associations acquired during performance in one task influence the way a following task is performed. Since perceiving an action and its consequences is thought to automatically activate the equivalent motor representation in the observer (e.g., De Maeght & Prinz, 2004; Prinz, 1997), in the present study we assessed whether action-effect associations can be acquired even when the action producing an effect is not visible and whether this learning (from now on, observational learning) can influence the way a subsequent task is performed. Furthermore, since there is increasing evidence that observer's motor abilities seem to be crucial for processing others' actions and their effects (e.g., Ambrosini, Sinigaglia, & Costantini, 2012), we tested whether observational learning takes place when the observer's potential actions are prevented (e.g., Ambrosini et al., 2012; Caggiano, Fogassi, Rizzolatti, Their, & Casile, 2009; Costantini, Ambrosini, Tieri, Sinigaglia, & Committeri, 2010; Gibson, 1977; Liepelt et al., 2009).

We employed a modified version of a paradigm, the Transfer of Learning (ToL) paradigm, that has been widely used to assess perceptual-motor learning in spatial stimulus–response compatibility tasks both in individual (e.g., Proctor & Lu, 1999) and joint (Ferraro, Iani, Mariani, Milanese, & Rubichi, 2011; Ferraro et al., 2012; Milanese, Iani, & Rubichi, 2010; Milanese, Iani, Sebanz, & Rubichi, 2011) action settings.

In the ToL paradigm, participants first practice on a spatial compatibility task in which they are required to press a left key when a stimulus appears in a right location and a right key when a stimulus appears in a left location; thus, the task defines spatially incompatible stimulus–response (S–R) associations. Subsequently, the participants perform a task in which they are required to respond to a non-spatial feature (e.g., color) of stimuli presented in left and right locations. Without prior practice, responses are faster and more accurate when stimulus and response locations spatially correspond than when they do not correspond, a phenomenon called the Simon effect (e.g. Figliozzi, Silvetti, Rubichi, & Doricchi, 2010; Iani, Ricci, Baroni, & Rubichi, 2009; Rubichi, Nicoletti, Pelosi, & Umiltà, 2004; Simon & Rudell, 1967; see Proctor & Vu, 2006; Rubichi, Vu, Nicoletti, & Proctor, 2006 for reviews). However, the Simon effect is reduced, eliminated, or even reversed when participants perform the spatial compatibility task in which they are required to respond to stimulus location by emitting a spatially incompatible response in advance (e.g., Iani, Rubichi, Gherri, & Nicoletti, 2009; Proctor & Lu, 1999). This reduction or elimination (from now on, Transfer-of-learning effect or ToL) is thought to occur because responding for a certain amount of trials with a spatially incompatible mapping strengthen the non-corresponding association between a stimulus and a response. Consequently, this association continues to affect performance even when the task is changed and the response should no longer be emitted on the basis of a spatial stimulus feature. This may occur because, if the same S–R association is repeatedly used, it is stored into the memory (Logan, 1988) and, when a certain stimulus appears again, the response that has been associated with it for repeated instances is retrieved automatically, irrespective of a change in task instructions.

In the present series of experiments we modified the ToL paradigm in the following ways. First, participants were required to passively observe the spatial compatibility task before actively performing a Simon task. Second, during the passively observed task participants did not see a real responding agent, but only the consequences of computer-generated responses.

In Experiment 1, we compared the effects of a passively observed practice with either a spatially compatible or incompatible stimulus–response (S–R) association. We found that the Simon effect was absent following the passively observed spatially incompatible practice, while it was evident following the passively observed spatially compatible practice. To assess whether a passively observed practice leads to the acquisition of incompatible perceptual-motor associations between stimuli and evoked responses that influence the way a subsequent task is performed, in Experiments 2 and 3 we manipulated the participants' possibility to act during the observed practice. Specifically, we tested whether observational learning depends on the presence of a response device and on the observer's possibility to operate on it. In Experiment 2, during the observed spatially incompatible practice participants were prevented from potentially acting either because a plexiglas barrier separated the participant from the response device rendering it out of reach, or because the participant's hands were tied, or, because the device affording a response was absent. In Experiment 3, the plexiglas separating the participant from the response box presented an opening that could allow him/her to potentially reach and interact with the response device. If, for the ToL effect to occur, the presence of a response device is the crucial factor, no effect should be evident when a response device is missing. If participants also need to be able to potentially reach the device and interact with it, the observation of an incompatible practice should have no effect in the three conditions of Experiment 2, while in Experiment 3 it should lead to the same behavioral consequences observed when the practice task is actually performed.

2. Experiment 1

This experiment was aimed at assessing whether observing the mere effects of a spatially incompatible practice influences performance on a subsequently performed Simon task, similarly to what occurs when the practice task is actually performed. During the practice task, participants were required to observe, without acting, the consequences of responses generated by the computer. Responses were signaled by the turning on of either the leftmost or the rightmost button of a response device positioned on a table in front of the participants (Fig. 1a). Participants were told that this event, that caused stimulus disappearance, was generated by the computer in response to the stimulus and that the same effect could have been obtained by pressing the button that turned on. The spatial association between the light (i.e., the response) and the stimulus could be either compatible or incompatible. In the following active transfer session, they were required to perform a standard Simon task by responding to stimulus color.

2.1. Methods

2.1.1. Participants

Thirty-two undergraduate students (24 females; age range 18–32 years; mean age 21.9 years) were randomly assigned in equal proportions to one of the two experimental conditions (''compatible'' vs. ''incompatible'' passive observational practice). All participants gave informed consent, reported normal or corrected-to-normal vision and were naïve as to the purpose of the experiment.

2.1.2. Apparatus and stimuli

Stimuli in the passively observed spatial compatibility task were white solid squares, whereas stimuli in the actively practiced Simon task were red or green solid squares (4.5×4.5 cm). They were presented on a 19′ color screen controlled by an IBM computer, 9 cm to the left or to the right of a central fixation cross (1×1 cm).

The observed responses to the spatial compatibility task were signaled by either the leftmost or rightmost button of an *E*-prime response box turning on. The turning on of the response box button caused the disappearance of the stimulus. The response box was positioned on the computer table in front of the participant at a distance of 40 cm.

Participants responded to the Simon task by pressing the ''*z*'' or ''–'' key of a standard Italian keyboard with

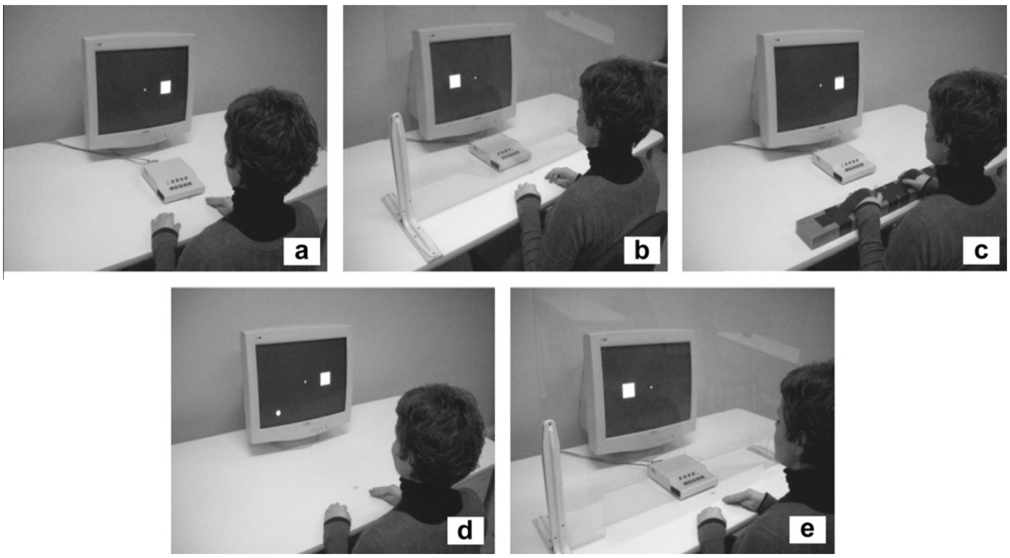

Fig. 1. Illustration of the experimental setting used in the passive observational practice sessions of the three Experiments. In Experiment 1, the response box was positioned in front of the participant (a). In Experiment 2, in the ''unreachable response device'' condition, the response box was positioned behind a plexiglass barrier (b), in the ''constrained hands'' condition, participant's hands were tied to the table (c), and in the ''response device absent'' condition, the response box was absent (d). In Experiment 3, the plexiglass barrier presented an horizontal opening (e.).

the left or right index finger, respectively. Viewing distance was about 70 cm.

2.1.3. Design and procedure

The experiment consisted of two consecutive sessions separated by a 5-min interval. In the first session (i.e., passive observational practice session) participants sat in front of the computer monitor and observed, without emitting any response, the computer performing a spatial compatibility task. In the second session (i.e., active transfer session), participants were required to execute a Simon task.

In the spatial compatibility task (passive observational practice session), a trial began with the presentation of a fixation cross at the center of a black background. After 1 s. the stimulus appeared to the right or to the left of fixation. After 350 ms the designed button on the response box turned on for 200 ms, causing stimulus disappearance. The stimulus disappeared as soon as one of the response buttons turned on, suggesting a clear cause-effect relation. Participants were instructed to passively observe. They were told that the turning on of the response box button signaled the emission of a response by the computer and that the button that turned on was the one that they should have pressed to respond to the stimulus. For half of the participants, when a stimulus appeared on the right, the rightmost button on the device turned on, whereas when a stimulus appeared on the left, the leftmost button turned on (compatible-mapping condition). For the other half, when a stimulus appeared on the right, the leftmost button on the device turned on, whereas when a stimulus appeared on the left, the rightmost button turned on (incompatible-mapping condition). This task consisted of 300 trials divided into 3 blocks of 100 trials each.

In the Simon task (active transfer session), the response box was replaced with a standard keyboard and participants were instructed to press the right or the left key in response to stimulus color with their left and index fingers, respectively. Half of the participants in each condition responded to red stimuli by pressing the right key ("–") and to green stimuli by pressing the left key ("*z*"). The other half experienced the opposite mapping rule.

A trial began with the presentation of a fixation cross at the center of a black background. After 1 s. the stimulus appeared to the right or to the left of fixation and remained visible for 800 ms. Maximum time allowed for a response was 1200 ms. No feedback was provided. The task consisted of 12 practice trials and 160 experimental trials divided into two blocks of 80 trials each.

2.2. Results and discussion

Errors in the Simon task (active transfer session) were very few (3%) and were not further analyzed. Correct RTs were entered into a repeated-measures analysis of variance (ANOVA) with trial correspondence (corresponding vs. non corresponding trials) as within-subject factor andlight (i.e., response)-stimulus mapping (compatible vs. incompatible light-stimulus mapping) as between-participants factor. The Bonferroni's test was used for all post hoc comparisons.

The analysis showed a significant effect of correspondence, $F(1,30) = 21.10$, $p < .001$, $\eta_p^2 = .41$, and a significant interaction between light-stimulus mapping and correspondence, $F(1,30) = 5.52$, $p < .03$, $\eta_p^2 = .15$, as shown in Fig. 2. post hoc comparisons showed that the difference between corresponding and non-corresponding trials (i.e., the Simon effect) was significant only when the light-stimulus

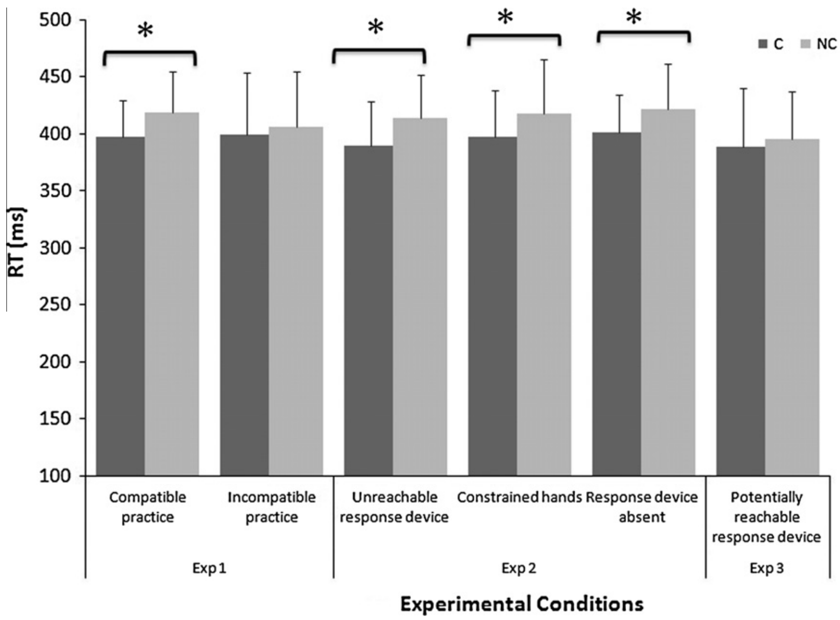

Fig. 2. Mean RTs (±SD) in ms for corresponding and non-corresponding trials in the actively performed Simon task for the experimental conditions of the three experiments. Asterisk denotes significant differences. C = Corresponding; NC = Non-corresponding.

mapping was compatible (22 ms; Cohen's $d = .63$). When the mapping was incompatible, no effect was evident (7 ms, n.s.; Cohen's $d = .44$).

The elimination of the Simon effect following the observed incompatible practice suggests that, similarly to what occurs when the practice task is actually performed (e.g., Iani, Rubichi et al., 2009; Proctor & Lu, 1999), a passively observed practice may lead to the acquisition of incompatible associations between stimuli and evoked responses. These associations influence the way the subsequent Simon task is performed, eliminating the conflict at the basis of the Simon effect. According to the reasoning highlighted in the Introduction, this may occur because perceiving specific events in the environment (i.e., stimulus offset) is sufficient to prime the motor means to achieve them. This supposed motor simulation leads to the same behavioral consequences obtained following actual action execution, that is, to perceptual-motor learning effects.

To note, it has recently been claimed that for observational learning to occur the agent should be present and actions should be visible. For instance, Paulus, van Dam, Hunnius, Lindemann, and Bekkering (2011) asked their participants to first observe another person pressing two buttons that triggered two different auditory tones. In a subsequent task, the same tones were presented as stimuli to which participants had to respond to with key-presses. Responses in this latter task were faster if the stimulus–response mapping was compatible with the previously observed action-effect association, hence, suggesting that bidirectional associations between actions and distal effects can be acquired through observational learning. However, inconsistent with the results of our Experiment 1, no advantage for the compatible mapping was evident when participants merely believed that the observed effects were caused by another person's action, hence suggesting that the presence of an agent is necessary to acquire novel action-effect associations. It is important to note that Paulus et al.'s paradigm differs from ours in one important aspect. In Paulus et al.'s study the relevant stimulus was followed by a yellow circle appearing on the left or right side of the screen (which, in the action belief condition, signaled the other agent's response) and by a tone. As suggested by the same authors, there is the possible confound that during the observational phase participants learned the association between the other's action and the circle, rather than between the other's action and the tone. Since in the subsequent test phase participants were required to respond to the tones, the effects of this association could not be assessed.

3. Experiment 2

Studies on associative learning indicate that if two sensory events co-occur repeatedly in temporal proximity, their representations are connected (e.g., Rescorla & Wagner, 1972). Hence, it could be possible that, in Experiment 1, during the incompatible practice, participants did not learn an incompatible association between the stimulus and the evoked response (i.e., perceptual-motor learning) but rather, they learned a spatially incompatible association between the lightening up of the response box button, signaling a response, and stimulus offset (that is, a stimulus-stimulus association). If this were the case, the effects evident in the incompatible-practice condition of Experiment 1 would not be necessarily due to the activation of a motor response following perception of action effects. To exclude this alternative explanation, and to support a genuine perceptual-motor basis of the observed learning effect, in Experiment 2 we manipulated the participants' possibility to potentially act on the response device during the observed practice task.

More precisely, for one group of participants, a transparent plexiglas barrier was interposed between them and the response box, thus rendering it unreachable (Fig. 1b); for a second group, the response box was positioned in front of them but their hands were tied to the table (Fig. 1c) thus preventing them from potentially acting on the device; finally, for a third group, the response box was absent and responses to the practice task were signaled by a yellow circle appearing on the screen (Fig. 1d).

If the effect evident in the incompatible-mapping condition of Experiment 1 was due to perceptual-motor learning, no ToL effect should be evident when the participants are prevented from potentially acting. Similarly, no ToL effect should be evident if during the practice task there is no response device that affords an action (Gibson, 1977). This would be in line with recent studies showing that not only observers' motor abilities but also their being in a position to exercise them are crucial for processing others' actions, making sense of them and predicting their effects (e.g., Ambrosini et al., 2012; Caggiano et al., 2009; Costantini et al., 2010; Liepelt et al., 2009). On the contrary, if what participants acquire during the observed practice phase is an association between two stimuli, then the effect of this learning should not depend on the participants' possibility to act and hence should be evident in all the experimental conditions.

3.1. Methods

3.1.1. Participants

Forty-eight new participants (38 females; aged 19–28 years; mean 20.7 years), selected as before, were randomly assigned in equal proportions to the three experimental conditions of Experiment 2 ("response device absent", "response device unreachable" and "constrained hands" conditions).

3.1.2. Apparatus and stimuli

Stimuli for the two tasks were the same as used in Experiment 1. As in the passive observational practice session of Experiment 1, in the "unreachable response device" and "constrained hands" conditions, the observed responses to the spatial compatibility task were signaled by either the leftmost or rightmost button of an *E*-prime response box turning on. Since in the "no response device" condition the response box was removed, observed responses were signaled by a circle (1 cm diameter) appearing in the bottom left or bottom right part of the screen for 200 ms. The turning on of the response box button (in the "unreachable response device" and "constrained hands" conditions) or the appearance of the circle (in the" response device absent" condition) caused the disappearance of the stimulus.

When present, the response box was positioned on the computer table in front of the participant at a distance of 40 cm. In the "unreachable response device" condition a transparent plexiglas barrier (100 cm high, 70 cm width) was interposed between the participant and the response box. In the "constrained hand" condition, no plexiglas was present and participants' hands were tied to the table by means of a wooden frame.

3.1.3. Design and procedure

Design and Procedure were the same as in Experiment 1 except for what follows. In the passive observational practice session of this experiment only the incompatible mapping was used and participants observed the computer generated responses under one of three possible conditions. More precisely, for one third of the participants, a transparent plexiglas barrier was interposed between the participant and the response box ("unreachable response device" condition); for another third, the response device was present but their hands were tied to the table by means of an horizontal wooden frame ("constrained hands" condition); finally, for the remaining third of participants, no response box was present ("response device absent" condition). In the "unreachable response device" and "constrained hands" conditions the computer-generated response was signaled by the button on the response box turning on. The button that turned on was always contralateral to the position of the stimulus. In the "response device absent" condition it was signaled by a yellow circle appearing in the bottom left or bottom right part of the screen. The circle always appeared contralaterally to the position signaled by the stimulus. The stimulus disappeared as soon as one of the response buttons turned on or a circle appeared, suggesting a clear cause-effect relation. Participants were told that the turning on of the response box button or the appearance of the circle signaled the emission of a response.

3.2. Results and discussion

Errors were very few (2.9%) and were not further analyzed. Correct RTs for the Simon task were submitted to a repeated measures ANOVA with trial correspondence (corresponding vs. non-corresponding trials) as within-participant factor and condition ("unreachable response device" vs. "constrained hands" vs. "response device absent") as between-participants factor.

The analysis showed no main effect of condition ($F < 1$) and a main effect of correspondence, $F(1,45) = 52.04$, $p < .001$, $\eta_p^2 = .54$, with faster response times in corresponding than in non-corresponding trials (396 and 418 ms, respectively). The Simon effect was of 24 ms (Cohen's $d = .57$) in the "response device unreachable" condition, 21 ms (Cohen's $d = .50$) in the "constrained hands" condition and 21 ms (Cohen's $d = .60$) in the "response device absent" condition (see Fig. 2). These effects did not differ as indicated by the lack of a significant interaction between correspondence and condition ($F < 1$).

To compare the magnitude of the Simon effect found in the three conditions of Experiment 2 with the effect evident in the compatible-mapping condition of Experiment 1, we computed for each participant the difference between mean RTs on non-corresponding trials and mean RTs on corresponding trials and submitted the resulting values to an ANOVA with condition as independent variable. This analysis indicated that the effect found in the three conditions of Experiment 2 did not differ from the effect evident in the compatible-mapping condition of Experiment 1 ($F < .1$).

These results suggest that the elimination of the Simon effect found in Experiment 1 was motoric in nature. Hence, it is plausible to suggest that during the passively observed practice, motor representations of the actions suited to obtain the observed environmental changes (i.e., stimulus offset) were activated. Our findings also show that the presence of the responding device is necessary but not sufficient for observational learning to occur. Rather, participants should be potentially able to operate the device. The ToL effect did not occur when participants could not potentially operate on the response device executing the practice task either because it was presented beyond a transparent plexiglas barrier and hence felt outside the participants' peripersonal space (Caggiano et al., 2009; Costantini et al., 2010), or because participants' hands were tied to the table and hence they were unable to act (Ambrosini et al., 2012; Liepelt et al., 2009) or because there was no response device affording a potential action (Gibson, 1977).

4. Experiment 3

This experiment was aimed at further assessing whether for observational learning to occur observers should be able to potentially act. To this aim, as in the "unreachable response device" condition of Experiment 2, participants observed the spatially incompatible practice behind a transparent plexiglas. Differently from Experiment 2, the barrier presented an opening in which they could potentially insert their hands to reach the device (Fig. 1e). If observational learning occurs only if the execution of specific actions suited to obtain the observed effects is potentially possible, then no Simon effect should be evident.

4.1. Methods

4.1.1. Participants

Sixteen new participants (13 females, aged 19–28 years, mean 21.8 years), selected as before, took part in Experiment 3.

4.1.2. Apparatus, Stimuli and Procedure

Apparatus, Stimuli and Procedure were the same used in the "unreachable response device " condition of Experiment 2 with the only exception that the transparent barrier interposed between the participants and the response box presented an opening (15 cm high, 60 cm width) in the bottom part allowing them to insert their hands to reach for the response device (Fig. 1e). Participants were required to insert their hands in the opening to press the response box button to start the experiment and to resume it after a break. During the passive observational practice session, their hands were positioned on the table, behind the plexiglas.

4.2. Results and discussion

Errors were very few (2.6%) and were not further analyzed. Correct RTs for the Simon task were submitted to a repeated measures ANOVA with trial correspondence (corresponding vs. non-corresponding trials) as within-participant factor.

The difference between corresponding and non-corresponding trials (6 ms; Cohen's $d = .48$) did not reach significance, $F(1,15) = 1.84$, $p = .19$, $\eta_p^2 = .11$ (Fig. 2). To compare the magnitude of the Simon effect found in Experiment 3 with the effect evident in the "unreachable response device" condition of Experiment 2, we computed for each participant the difference between mean RTs on non-corresponding trials and mean RTs on corresponding trials and submitted the resulting values to an ANOVA with condition as independent variable. This analysis showed that the non-significant 6-ms effect found in the present Experiment significantly differed from the 24-ms effect evident in the "unreachable response device" condition of Experiment 2, $F(1, 31) = 6.21$, $p < .02$, while it did not differ from the 7-ms effect found in the incompatible-mapping condition of Experiment 1, $F < 1$.

This result supports the view that, for observational learning to occur, observers should be able to potentially act. Indeed, if the plexiglas separating the participants from the response device presents an opening in which they can potentially insert their hands to reach the device, no Simon effect is evident in the subsequent actively performed Simon task. It is plausible that when participants can potentially act, reach the device and interact with it, the observation of action effects during the passive observational practice task triggers a motor simulation that leads to the same behavioral consequences observed when the practice task is actually performed.

5. General discussion

The present study was aimed at identifying the conditions under which observational learning occurs by assessing whether it is affected by the visibility of an action producing perceived environmental effects and by the observer's possibility to act during observation. To this end, in three experiments participants were required to observe a spatial compatibility task in which only the effects of computer-generated responses were visible, before executing a Simon task. It is known that when individuals perform a spatial compatibility task with an incompatible mapping before performing a Simon task, the Simon effect is reduced, absent of even reversed. This is thought to occur because the incompatible perceptual-motor association acquired during practice transfers to and influences the way the subsequent Simon task is performed, eliminating the conflict at the basis of the Simon effect (e.g., Iani, Rubichi et al., 2009). Since perceiving an action or its consequences is thought to automatically activate the equivalent motor representation in the observer (e.g., De Maeght & Prinz, 2004; Prinz, 1997), we hypothesized that perceptual-motor associations could be acquired also through the mere observation of environmental action effects, even when the action itself was not visible. Furthermore, since there is recent evidence that observers' motor abilities are crucial for processing others' actions (e.g., Ambrosini et al., 2012), we assessed whether this observational learning could take place when the observer's potential actions were prevented (e.g., Ambrosini et al., 2012; Caggiano et al., 2009; Costantini et al., 2010; Liepelt et al., 2009).

The results of Experiment 1 showed that observational learning may derive from the observation of environmental action effects even when the action itself is not visible. Indeed, the Simon effect was eliminated following passive observation of a spatially incompatible practice, while it was present following passive observation of a spatially compatible practice. These results replicate those obtained when the practice task is actually performed (e.g., Iani, Rubichi et al., 2009; Proctor & Lu, 1999) and indicate that what is learned during the passively observed practice transfers to the Simon task.

It is plausible to suggest that the observation of remote environmental effects triggers in the observer the activation of the specific action representations suited to obtain the same effects.

Such a conclusion is consistent with the results of previous studies showing that motor simulation is triggered when the action of the other is predicted (e.g., Kilner, Vargas, Duval, Blakemore, & Sirigu, 2004; Liepelt, von Cramon, & Brass, 2008).

Crucially, the results of Experiments 2 and 3, in which we manipulated the observer's possibility to act on the response device, showed that observational learning occurs only if the execution of the specific actions is potentially possible. Indeed no evidence of transfer of learning was found when, during passive observation, the participants' hands were tied, or a transparent barrier prevented them from potentially interacting with the response device, or no response device was present. Differently, a ToL effect was observed when a response device was present and interactions with it were potentially possible (that is, no barrier was present or the barrier presented an opening in which participants could potentially insert their hands to reach the response device). These results allowed us to conclude that during the incompatible practice participants learned an incompatible association between the stimulus and the evoked response rather than a spatially incompatible association between the turning on of the response box button, signaling a response, and stimulus offset. Most important, they indicate that, during passive observation, our motor system automatically processes physical and environmental factors constraining action execution, and that action representations are activated only if the observer is in the position to potentially act (Costantini, Ambrosini, Sinigaglia, & Gallese, 2011; Gallese & Sinigaglia, 2011a).

Most importantly, the present results have broad implications for researchers investigating perception–action links. Indeed, they show that perceiving environmental effects the observer knows how to reproduce (that is, for instance, perceiving stimulus disappearance and knowing that the same effect could be obtained by pressing a specific key on a response device) is sufficient to activate the motor code corresponding to the action suitable to produce them (i.e., the keypress).

They also have implications for researchers investigating observational learning. The understanding of the mechanisms underlying observational learning and of the conditions under which it occurs is particularly valuable because observational learning is fundamental under many circumstances of our lives (e.g., Bandura, 1986; Sheffield, 1961). The present study showed that stimulus–response associations may be acquired through passive observation of the environmental effects of a response. Similarly to what occurs when stimulus–response associations are performed, this learning affects the way a subsequent task is performed. Importantly, our results show that the motor system may play a crucial role in this type of learning. Indeed, we showed that ToL effects occurred only if the observer, during the observed task, was in the position to potentially act. Although these results were found using a paradigm assessing learning of simple S–R associations, we believe they may be relevant for the learning of more complex motor tasks.

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