Social Motor Priming: When interference facilitates motor execution

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Many daily activities involve synchronizing with other people's actions. Previous literature has revealed that a slowdown of performance occurs whenever the action to be carried out is different to the one observed (i.e., visuomotor interference). However, action execution can be facilitated by observing a different action if it calls for an interactive gesture (i.e., social motor priming). The aim of this study is to investigate the costs and benefits of spontaneously processing a social response and then executing the same or a different action. Participants performed two different types of grips, which could be either congruent or not with the socially appropriate response and with the observed action. In particular, participants performed a precision grip (PG; thumb-index fingers opposition) or a whole-hand grasp (WHG; fingers-palm opposition) after observing videos showing an actor performing a PG and addressing them (interactive condition) or not (non-interactive condition). Crucially, in the interactive condition, the most appropriate response was a WHG, but in 50 percent of trials participants were asked to perform a PG. This procedure allowed us to measure both the facilitator effect of performing an action appropriate to the social context (WHG) – but different with respect to the observed one (PG) – and the cost of inhibiting it (social-compatibility effects). These effects were measured by means of kinematical analysis. Results show that, in terms of reaction time and movement time, the interactive request facilitated (i.e., speeded) the socially appropriate action (WHG), whereas interfered with (i.e., delayed) a different action (PG), although observed actions were always PG. This interference also manifested with an increase of maximum grip aperture, which seemingly reflects the concurrent representation of the socially appropriate response. Overall, these findings represent a step forward in research concerning the influence of social contexts on action-perception coupling.

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Abstract

Many daily activities involve synchronizing with other people's actions. Previous literature has revealed that a slowdown of performance occurs whenever the action to be carried out is different to the one observed (i.e., visuomotor interference). However, action execution can be facilitated by observing a different action if it calls for an interactive gesture (i.e., social motor priming). The aim of this study is to investigate the costs and benefits of spontaneously processing a social response and then executing the same or a different action. Participants performed two different types of grips, which could be either congruent or not with the socially appropriate response and with the observed action. In particular, participants performed a precision grip (PG; thumb-index fingers opposition) or a whole-hand grasp (WHG; fingers-palm opposition) after observing videos showing an actor performing a PG and addressing them (interactive condition) or not (non-interactive condition). Crucially, in the interactive condition, the most appropriate response was a WHG, but in 50 percent of trials participants were asked to perform a PG. This procedure allowed us to measure both the facilitator effect of performing an action appropriate to the social context (WHG) – but different with respect to the observed one (PG) – and the cost of inhibiting it (social-compatibility effects). These effects were measured by means of kinematical analysis. Results show that, in terms of reaction time and movement time, the interactive request facilitated (i.e., speeded) the socially appropriate action (WHG), whereas interfered with (i.e., delayed) a different action (PG), although observed actions were always PG. This interference also manifested with an increase of maximum grip aperture, which seemingly reflects the concurrent representation of the socially appropriate response. Overall, these findings represent a step forward in research concerning the influence of social contexts on action-perception coupling.

Introduction

A wealth of resent research has been devoted to investigating how we anticipate, monitor and respond to other's actions. Most of the studies on perception-action coupling have corroborated the idea that observing an action automatically triggers an inclination to imitating it (for a review see (Heyes, 2011). Consistent behavioral evidence shows that participants are facilitated (e.g., shorter reaction times and increased accuracy) if the action to be carried out has been previously observed. Visuomotor priming, in particular, regards the facilitation to perform an action congruent with the observed one versus the difficulty to execute the same action during the observation of a different one (visuomotor interference; Brass et al., 2000; Brass, Bekkering & Prinz, 2001; Edwards, Humphreys & Castiello, 2003; Brass, Derrfuss & von Cramon, 2005; Gowen & Poliakoff, 2012). While visuomotor priming is relatively well-studied, it is less clear how this mechanism is modulated when others' actions are instrumental for the fulfillment of a specific goal. If, for example, someone holding a mug by its handle – using a three-digit grasp – hands it to us, we automatically grasp the 'available' surface with a whole-hand grip, rather than imitating the observed grip. In this case, the two actions are physically incongruent, yet complementary. Recent findings have shown that the brain can easily resolve the conflict between the automatic tendency to imitate, and that to perform context-related complementary actions (for a review see Sartori & Betti, 2015). Brief periods of sensorimotor experience, in which participants are trained to perform a different action from the one observed, can indeed abolish (Cook et al., 2010) or reverse (Catmur et al., 2008) the visuomotor priming.

It then appears that action observation does not automatically lead to imitation, rather, depending on sensorimotor experience and on social context, observed actions could prime different responses (social-compatibility effect).

In this connection, social overlearned responses can modulate motor performance (Liepelt, Prinz & Brass, 2010; Flach et al., 2010), so that complementary response preparation can spontaneously overwhelm imitative responses (i.e., Social Responding; Wang & Hamilton, 2013; Hamilton, 2013). In this respect, Liepelt and colleagues (2010) described the *reversed compatibility* effect when observing a human right hand extended for a handshake: participants responded faster with their own right hand, not with their mirror hand (Liepelt, Prinz & Brass, 2010). This effect is driven by the strongly life-long learnt social response of responding with the non-mirror hand to handshaking.

On the other hand, evidence that online interference occurs when an given action has to be performed, but a concurrently observed movement elicits a complementary different grasp has been provided using a reach-to-grasp task (Chinellato, Castiello & Sartori, 2015; see also Krishnan-Barman, Forbes & Hamilton, 2017 for a review on the use of action kinematics to study social interactions). In particular, when participants were requested to execute a precision grip (PG) while concurrently observing an actress performing a PG –but asking for a whole-hand grasp (WHG) in response– an interference (i.e., a delay in reaction times, movement times, times to maximum grip velocity) was detected (Chinellato, Castiello & Sartori, 2015). This result suggests that observing an interactive gesture automatically generates an internal representation of the required response. Such representation can cause interference in the online execution of a different grasping movement, due to competition between the two motor plans. A recent study by Sacheli and colleagues (2018) investigated another aspect of motor interference. In their paradigm, the physical incongruence of a partner's movement was tested in a joint or in an isolated context. Interestingly, interference affected participant's motor performance to a lesser extent when they had to interact in a joint (music) task. Similar findings were also found by

Clarke and colleagues (2018). Notably, in these experiments the interference due to physical incongruence was decreased – not abolished – by the joint goal. This raises the possibility that motor interference is a continuum, rather than an on/off mechanism. We hypothesize that less resources – and therefore less interference – occurs as long as a joint action is well-learnt. Likewise, less interference occurs for a "second task" if the primary task is automatized (Castiello & Umiltà, 1987; Castiello, 1996; Guillery, Mouraux & Thonnard, 2013). Another possibility is that a simple effect of co-representation might explain the interference effect. In that case, motor impairment would not last in a postponed task.

Along these lines, the present study has been designed to specifically test whether social compatibility effects are long-lasting and can modulate the perception-action coupling even *after* action observation. To induce a full range of facilitation/interference effects, we devised a full-factorial experimental design (Fig. 1). Participants observed two videos of an actress: i) grasping a tablespoon with a PG, pouring sugar in a mug located nearby, and then stretching out her arm trying to pour some remaining sugar into a mug located out of her reach (Interactive action; Fig. 2a), ii) grasping a tablespoon with a PG, pouring sugar into the same first mug, and then returning to the starting point (Non-Interactive action; Fig. 2b). Notably, the Interactive action elicits a complementary response in an observer (see Sartori & Betti, 2015), that is a WHG toward the mug, to grasp it and bring it closer to the actress. Participants had the task to observe these perceptual events, to wait for an auditory 'Go' signal, and then to either grasp a spoon with a PG (50% of trials) or a mug with a WHG (50% of trials), depending on the 'Go' signal. Two baseline conditions, in which participants simply observed a fixation cross and performed the grasping tasks (i.e., PG and WHG trials), were also set. Given that participants always observed a PG action performed by the actress (i.e., grasping the spoon), we should expect a facilitator effect when they grasped the spoon (visuomotor priming) to the detriment of performing a different action (visuomotor interference). However, if the social request elicits the preparation of a WHG in response to what is observed, in the Interactive condition we should expect a facilitation in performing a WHG (social motor priming) to the detriment of performing a PG (social motor interference). See Figure 1 for a schematic representation of this set of hypotheses. With this in mind, the aim of the present study was to specifically investigate the benefits and costs associated with the processing of a social request in terms of facilitating the execution of an appropriate action (when grasping the mug with a WHG) and of its inhibition when task irrelevant (when grasping the spoon with a PG).

Materials & Methods

Participants

Sixteen right-handed volunteers (10 females and 6 males, between the ages of 21 and 31) participated in the experiment. A right-handed non-professional actor (female, 28 years old) was recruited for video-clips recording. All participants gave their informed written consent to participate in the study. The experimental procedures were approved by the University of Padua Ethical Panel by written consent (Ref. 2371) and were in accordance with the Declaration of Helsinki.

Stimuli

Two video-clips showed an actress: i) pouring sugar with a tablespoon (grasped with a PG) in a mug located nearby, and then stretching out her arm in an attempt to pour the sugar left in the tablespoon within a mug located out of her reach (Interactive action; Fig. 2a), ii) pouring sugar in the same mug, and then coming back to the starting point (Non-Interactive action; Fig.

2b). Crucially, the out-of-reach mug was placed in the video foreground, closer to the participant watching the video, thus eliciting a complementary reaction with a WHG when the actress was trying to reach for it. The mug was visible in the video foreground also when the actress was coming back to the starting point (Non-Interactive action), therefore controlling for possible affordance effects. All of the videos were taken from a frontal view and were equal in length (8.2 s). Since gaze is a crucial component of social interactions and could have biased the results, the actress's face was not visible. For the participants' prehension task we adopted a sugar spoon (130 mm length, the same sugar spoon observed in the videos) vertically inserted into a mug (90 mm diameter, the same mug observed in the videos). An affixed colored dot on the sugar spoon and on the mug was signaling the required thumb's contact-point to perform stable and consistent grasps across the experiment and across participants. Two auditory signals (a low-pitch tone, 300 Hz, 200 ms; and a high-pitch tone, 500 Hz, 200 ms) were adopted as 'Go' signals at the presentation of a white fixation cross, which lasted until the end of the trial (Fig. 3).

Procedure

The experimental set up is depicted in Figure 4. Participants sat on a chair in front of a table (900 x 900 mm), watched the videos that were presented on a 19" monitor (resolution 1280 x 1024 pixels, refresh frequency 75 Hz, background luminance of 0.5 cd/m^2) set at eye level (the eye-screen distance was 60 cm). A starting platform (60 x 70 mm; 5 mm thick) was attached 90 mm away from the table surface's edge and 50 mm away from the midsection. After video presentation, participants had to execute a reach-to-grasp movement towards either a spoon or a mug placed on a target platform (100 x 100 mm; 5 mm thick), located 350 mm from the starting platform. The experiment included six experimental conditions; notably, the observed grasp was always a PG:

- Interactive action, Performed PG (Interactive PG): participants performed a PG after observing the Interactive request toward the mug.
- Interactive action, Performed WHG (Interactive WHG): participants performed a WHG after observing the Interactive request toward the mug.
- Non-Interactive action, Performed PG (Non-Interactive PG): participants performed a PG after observing the Non-Interactive action.
- Non-Interactive action, Performed WHG (Non-Interactive WHG): participants performed a WHG after observing the Non-Interactive action.
- Baseline PG: participants performed a PG on the sugar spoon after observing a white cross presented at the center of the monitor for 6 s.
- Baseline WHG: participants performed a WHG on the mug after observing a white cross presented at the center of the monitor for 6 s.

The baseline conditions were performed before the experimental session to allow participants to familiarize with the ‘Go’ signals and to provide baseline data for both types of grasp. The experiment was composed of 60 trials (10 per condition, each lasting 11 s). The acoustic ‘Go’ signal was released at the offset of each video or at the offset of the fixation cross in the baseline conditions. Participants were instructed to begin their movements as soon as the ‘Go’ signal sounded and to perform either a PG or a WHG. Trials were presented in randomized order and the association between required type of grasp and corresponding auditory signal was counterbalanced across participants. The time interval between the end of the video and the presentation of the ‘Go’ signal was varied randomly to reduce rhythmical effects (1200-2400 ms range).

Kinematics recording

A 3D Optoelectronic SMART-D system (Bioengineering Technology and Systems, B|T|S|) was used to track the kinematics of the participant's right upper limb. Six digital infrared cameras (sampling rate 60 Hz) equipped with highly sensitive CCD sensors were placed in a semicircle at 1–1.2 meters from the table (Fig. 4a). The spatial resolution of the recording system was 0.3 mm over the field of view. Two reflective markers (0.25 mm in diameter) were placed on each participant's hand to measure the grasping component of the action (i.e., concerning finger pre-shaping and finger closing around the object), and one marker was placed on the wrist to measure the reaching component of the action (i.e., concerning hand transportation toward the target object). In particular, the three infrared reflective markers were taped to the following points: thumb (ulnar side of the nail), index finger (radial side of the nail), and wrist (dorsodistal aspect of the radial styloid process) (see Fig. 4b). Following data collection, the SMART-D Tracker software package (B|T|S|) was used to provide a 3D reconstruction of the markers' positions as a function of time.

Data analysis

The temporal delay between the 'Go' signal and movement onset (i.e., the time at which the tangential velocity of the wrist marker crossed a threshold of 5 mm/s and remained above it for longer than 500 ms) was computed as Reaction Time (RT). Movement Time (MT) was then computed as the time interval between reaching onset and end of grasping (i.e., the time at which the hand opening velocity crossed a threshold of 5 mm/s after reaching its minimum value and remained above it for longer than 500 ms). Further, the maximum distance reached by the 3D coordinates of the thumb and index finger (Maximum Grip Aperture, MGA) was extracted for each individual movement.

The mean values for each parameter of interest were determined for each participant and entered into repeated-measures 3x2 ANOVAs with Condition (Interactive, Non-Interactive, Baseline) and Type of grasp (PG, WHG) as within-subject factors. Preliminary analyses were conducted to check for normality, sphericity, univariate and multivariate outliers, with no violations noted. Bonferroni correction was applied and a significance threshold level of $p < 0.05$ was set for all statistical analysis.

Results

A significant interaction of Condition by Type of Grasp was shown for RTs [$F_{(2,30)} = 50.341$, $p < 0.001$, $\eta^2_p = 0.770$] and for MT [$F_{(2,30)} = 30.335$, $p < 0.001$, $\eta^2_p = 0.669$]. For MGA, a significant effect of Type of Grasp [$F_{(2,30)} = 12.292$, $p = 0.003$, $\eta^2_p = 0.450$] and a significant interaction of Condition by Type of Grasp [$F_{(2,30)} = 5.872$, $p = 0.007$, $\eta^2_p = 0.281$] emerged. The results obtained from the post-hoc contrasts exploring the interactions are graphically represented in Figure 5 and listed according to the main hypotheses:

Visuomotor priming

- RTs. Decreased RTs were found for the Non-Interactive PG compared to the Baseline PG condition ($p = 0.019$, $\eta^2_p = 0.400$; Fig. 5a).
- MT. Decreased MT was found for the Non-Interactive PG compared to the Baseline PG condition ($p = 0.015$, $\eta^2_p = 0.419$; Fig. 5b).

- MGA. No significant effect was found for the Non-Interactive PG with respect to the Baseline PG condition ($p = 1.00$, $\eta^2_p = 0.041$; Fig. 5c).

Visuomotor interference

- RTs. Increased RTs were found for the Non-Interactive WHG compared to the Baseline WHG condition ($p = 0.008$, $\eta^2_p = 0.466$; Fig. 5d).
- MT. Increased MT was found for the Non-Interactive WHG compared to the Baseline WHG condition ($p = 0.038$, $\eta^2_p = 0.348$; Fig. 5e).
- MGA. No significant effect was found for the Non-Interactive WHG with respect to the Baseline WHG condition ($p = 0.781$, $\eta^2_p = 0.084$; Fig. 5f).

Social motor priming

- RTs. Decreased RTs were found for the Interactive WHG compared to the Non-Interactive WHG condition ($p < 0.001$, $\eta^2_p = 0.780$) and to Baseline WHG values ($p = 0.002$, $\eta^2_p = 0.537$; Fig. 5d).
- MT. Decreased MT was found for the Interactive WHG compared to the Non-Interactive WHG condition ($p = 0.005$, $\eta^2_p = 0.499$) and to Baseline WHG values ($p = 0.036$, $\eta^2_p = 0.353$; Fig. 5e).
- MGA. No significant effect was found for the Interactive WHG with respect to Non-Interactive WHG ($p = 1.00$, $\eta^2_p = 0.005$) and to Baseline WHG values ($p = 0.633$, $\eta^2_p = 0.102$; Fig. 5f).

Social motor interference

- RTs. Increased RTs were found for the Interactive PG compared to the Non-Interactive PG condition ($p < 0.001$, $\eta^2_p = 0.689$) and to Baseline PG values ($p = 0.021$, $\eta^2_p = 0.393$; Fig. 5a).
- MT. Increased MT was found for the Interactive PG compared to the Non-Interactive PG condition ($p = 0.001$, $\eta^2_p = 0.584$) and to Baseline PG values ($p = 0.021$, $\eta^2_p = 0.395$; Fig. 5b).
- MGA. A significant effect was found for MGA. In particular, grip aperture was increased when performing a PG for the Interactive condition compared to the Non-Interactive condition ($p = 0.038$, $\eta^2_p = 0.349$) and to Baseline PG values ($p = 0.008$, $\eta^2_p = 0.463$; Fig. 5c).

Discussion

This study aimed to deeply investigate social motor priming effects. Our findings confirmed earlier research by showing that action observation facilitates congruent types of actions (visuomotor priming) and interferes with different types of actions (visuomotor interference), even in a postponed task. Our results extend this research by showing that interactive requests can facilitate delayed responses even if they are physically incongruent with respect to the observed actions (social motor priming). Moreover, interactive requests can interfere with inappropriate grasping actions (social motor interference) even if they are congruent with the observed ones. Interestingly, we also found a dissociation concerned with interference. Inhibiting visuomotor or social motor priming seems to involve distinct mechanisms. Social motor interference, indeed, inflicted a more serious cost on kinematics than visuomotor interference. MGA was significantly modulated when participants performed a PG, but the actor was calling for a WHG. No MGA modulation was observed when participants performed a WHG after observing a Non-Interactive PG. Given that grip amplitude covaries linearly with object size (Jakobson & Goodale, 1991), a change in MGA when performing the same observed action suggests that its modulation is seemingly due to the previously observed social request. This output (i.e., an increased hand aperture) possibly indicates the co-presence of another motor plan (i.e., a WHG). Previous reports on *online* observation-execution interference tasks (Chinellato, Castiello & Sartori, 2015) indicate that planning a socially-appropriate WHG had a repulsive effect on what was performed (i.e., decreasing the MGA of the PG). This effect was likely driven by a form of inhibition of the features shared by perception and action (for a review see Castiello, 1999). According to Schubö and colleagues (2001), the representations that underlie different activities, such as producing a movement while simultaneously coding a perceptual event, must be kept distinct so that the two activities can be carried out without interfering (Schubö, Aschersleben & Prinz, 2001). Rather, our results for the postponed task suggest an *integration* of the inhibited motor plan (i.e., a WHG) into the executed action. In future studies, the adoption of a double dissociation paradigm showing WHG movements and an object triggering a complementary PG (Sartori, Bucchioni & Castiello, 2013) will permit to ascertain that the effects documented here will generalize also to the execution of a different response action. Notably, contrary to previous studies (Newman-Norlund et al., 2007; van Schie, van Waterschoot & Bekkering, 2008; Poljac, Schie & Bekkering, 2009; Ocampo & Kritikos, 2010; Ocampo, Painter & Kritikos, 2012), our paradigm did not entail any imitative or complementary blocks and no instructions regarding the action to be performed were given before trials began.

The present data take previous results a step further by demonstrating that social motor priming, once spontaneously triggered, is rather impervious to be inhibited and can affect even postponed action execution. This might ultimately suggest that social motor priming is more pervasive than visuomotor priming, influencing both the reaching and the grasping components of performed actions. Is this due to the intrinsically social valence of the stimulus? In this regard, we recently provided evidence that activity in the primary motor cortex elicited by a complementary request is even impermeable to attention-diverting cues (Betti et al., 2017). Social motor preparation seems therefore to be a genuine automatic mechanism. Interestingly, interference due to observing a precision grip and subsequently perform a whole-hand grasp was partially reduced for the interactive compared to the non-interactive context (i.e., quicker RT and movement time). It seems therefore that joint action goals reduce visuomotor interference effects along a continuum, as it occurs in dual-task paradigms when the primary task is increasingly automatized. Notably, in a dual-task condition, motor interference occurs when a cognitive task slows down some aspects of motor performance (Guillery, Mouraux & Thonnard, 2013), indicating that they require cognitive resources. In contrast, if these aspects are not affected by the cognitive task, they reflect more automatic processes. Taken together, our results suggest that measuring a whole-hand grasp in the presence of a social request – calling for a precision grip – may constitute a proficient tool to assess the degree of social motor priming.

Social response: Low-level or high-level mapping?

According to the Social Associative Memory hypothesis, an associative mechanism would be in charge of matching certain actions to their natural social response, irrespective of who is actually performing the action (Chinellato et al., 2013; Chinellato, Castiello & Sartori, 2015). "If action B (e.g., take) usually follows action A (e.g., give), the observation of a partner executing A elicits the pre-planning of B by the observer. On the other hand, if the subject executes A, he expects to see the partner performing B in response" (Chinellato et al., 2013).

Here, extensive experience of carrying out complementary actions in a social context would result in automatically generating the complementary action when observing an action in a social context. Consistent literature on social Simon effects (Guagnano, Rusconi & Umiltà, 2010; Humphreys & Bedford, 2011; Dittrich et al., 2013) and the development of Stimulus-Response associations (Catmur, Walsh & Heyes, 2009) provides convergent data on the hypothesis of a low-level direct mechanism for the priming of different behaviors. Our results, based on a *postponed* interference effect, might indeed be attributable to general processes of associative learning (Catmur, Walsh & Heyes, 2009; Massen & Prinz, 2009).

An alternative account for the present data is the high-level mapping. The theory of event coding (TEC; Hommel & Elsner, 2009; Hommel, 2009) states that observed (and executed) actions are represented in the form of their distal consequences. The TEC is based on the common coding hypothesis, which claims that perception and action rely on shared cognitive representations. According to the TEC, translating a perceived human movement into corresponding motor programs would function as an emulator, tracking the behavior of conspecifics in real time to generate predictions of an unfolding action (Wilson & Knoblich, 2005). Our data, on the contrary, show that observing others' behaviors rapidly activates appropriate complementary motor plans in an observer. In fact, since the distal goal of the actor is to reach the distant cup and the most efficient action to do it (by herself) would be slightly rising from her seat, motor prediction should have activated in the observer the corresponding leg muscles, rather than right-hand muscles. On the other hand, it is plausible that both a predictive and a social motor response preparation might have taken place, as we recently demonstrated (Sartori et al., 2015).

In conclusion, the reported effects are an example of a spontaneous tendency to fulfill the request embedded in a social interaction. This might be confirmed by the fact that when debriefed at the end of the experimental session, the 80 percent of participants spontaneously reported that they were ready to lift the salient object toward the model. It could be argued that attention played a role in modulating motor priming and that the actor's hand – moving toward the object – was simply more salient then the hand moving back to the starting position, without the effect being intrinsically a social motor priming. If this were the case, then a simple arrow presented instead of the hand would have produced similar findings. However, results from previous studies in which the social request was substituted by an arrow did not provide support for this view (Flach et al., 2010; Sartori et al., 2011). Rather we suggest that the motor system is preferentially tuned to meaningful actions of interactive partners and social motor preparation is so automatic that interference might become facilitation.

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Figure 1

Experimental Hypotheses

a) Visuomotor priming is expected when the performed grip (PG) is matched with the observed non-interactive action. b) Visuomotor interference is expected when the performed grip (WHG) is mismatched with the observed non-interactive action. c) Social motor priming is expected when the performed grip (WHG) is matched with the social request directed to the mug. d) Social motor interference is expected when the performed grip (PG) is mismatched with the social request directed to the mug.

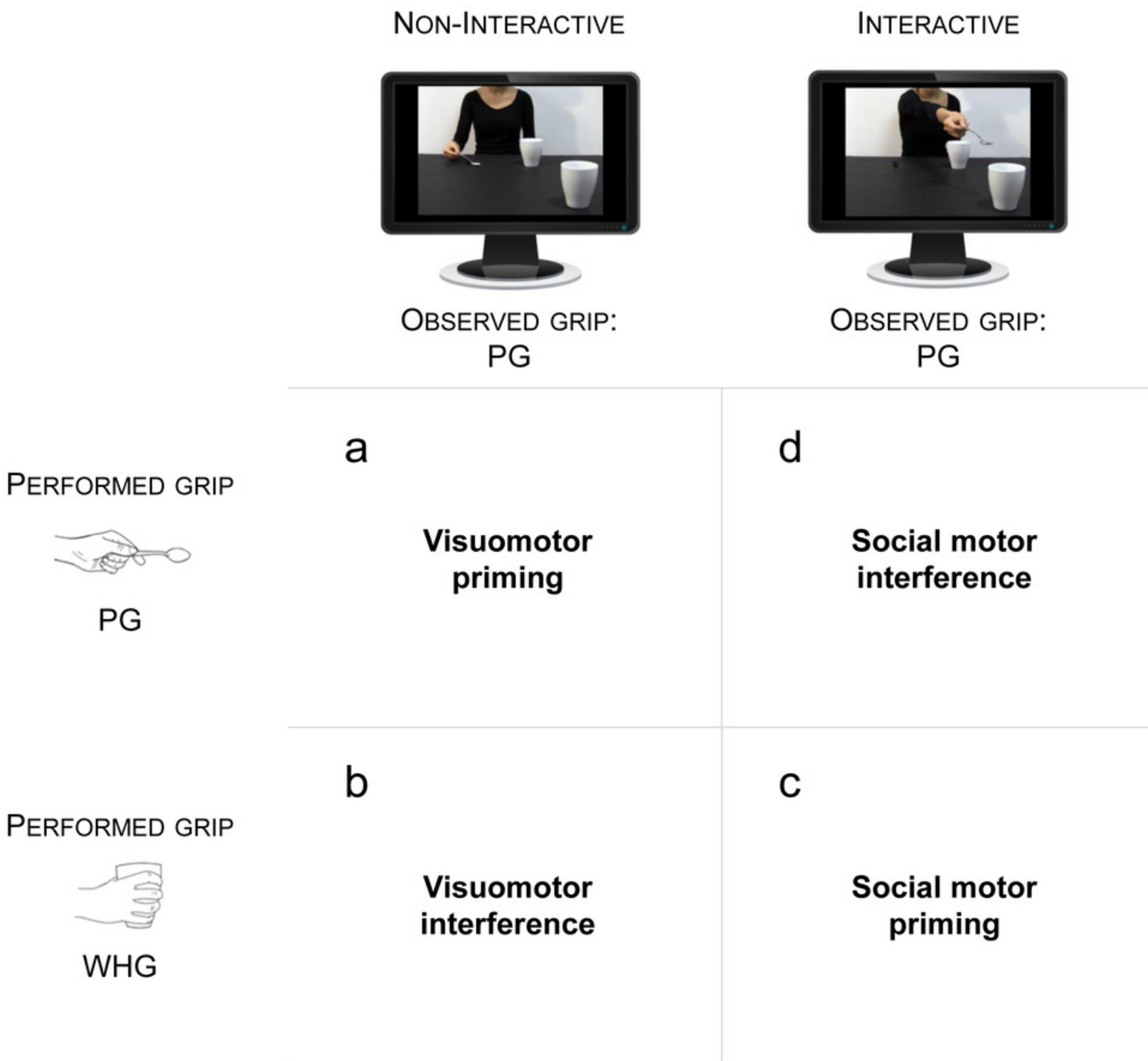
NON-INTERACTIVE
INTERACTIVE
OBSERVED GRIP: PG
OBSERVED GRIP: PG
PERFORMED GRIP
PG
PERFORMED GRIP
WHG
a
Visuomotor priming
d
Social motor interference
b
Visuomotor interference
c
Social motor priming

Figure 2

Experimental stimuli

a) Interactive action: The actress pours sugar with a tablespoon (precision grip; PG) in a mug located nearby, and then stretches out her arm trying to pour some sugar into a mug located out of her reach (red circle). Crucially, this mug is placed in the video foreground, thus requiring the observer's intervention to bring the mug closer. b) Non-Interactive action: The actress pours sugar in the same mug, and then comes back to the starting point.

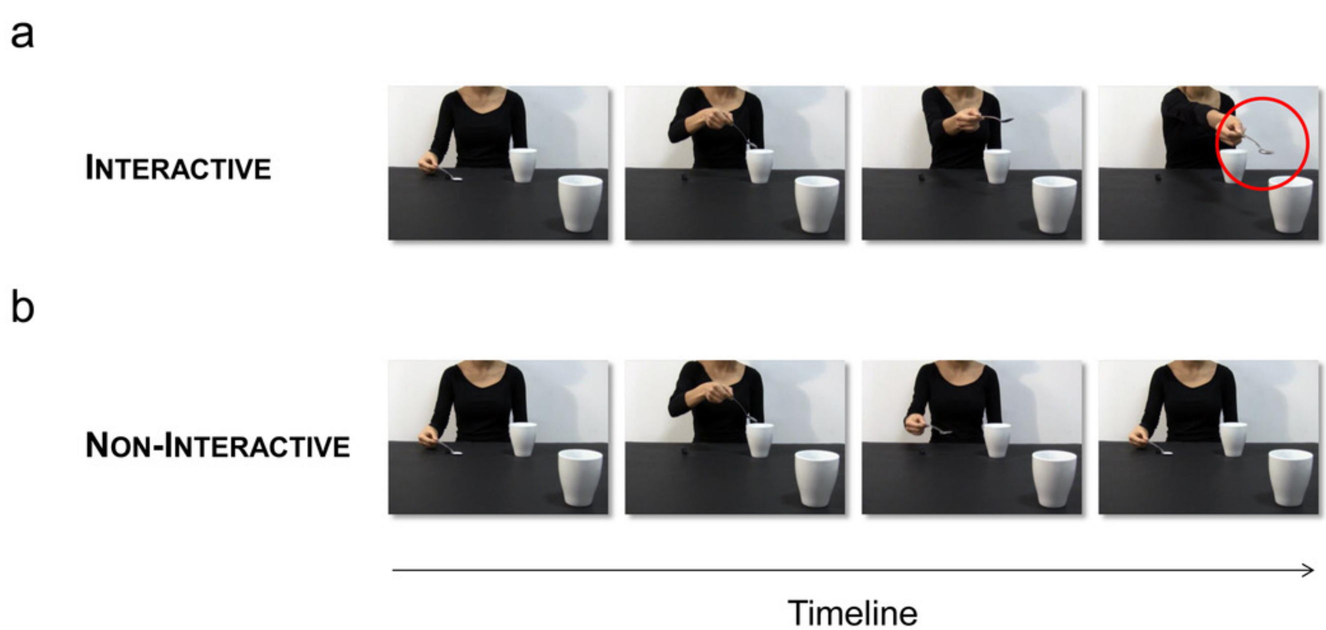

Figure 3

Timeline

During the Interactive condition, the participants observed a video showing an actress stretching out her arm trying to pour some sugar into a mug located close to them, thereby inviting them to grasp it. Depending on the specific type of 'Go' signal, they then performed a reach-to-grasp task on the mug or on the spoon located on a target platform.

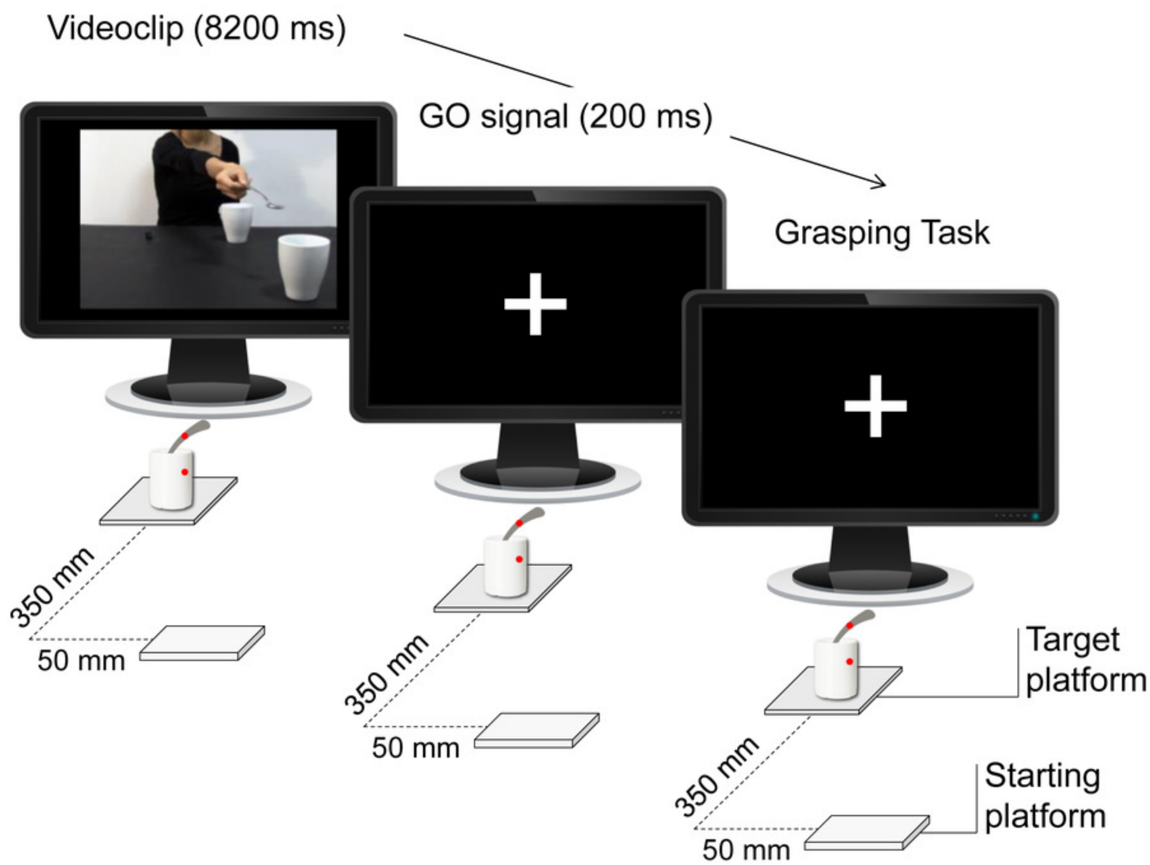

Figure 4

Set up

a) A 3D Optoelectronic SMART-D system was used to track the kinematics of the participant's right upper limb by means of six infrared cameras equipped with highly sensitive CCD sensors. Each participant sat in front of a table and had to watch the video clips (Interactive, Non-Interactive) that were presented on a monitor. b) The participant's right elbow and wrist were resting on the table surface with the hand resting on a starting platform. To measure the grasp and reach components of the movement, retro reflecting markers were taped to the following points: thumb, index finger, and wrist.

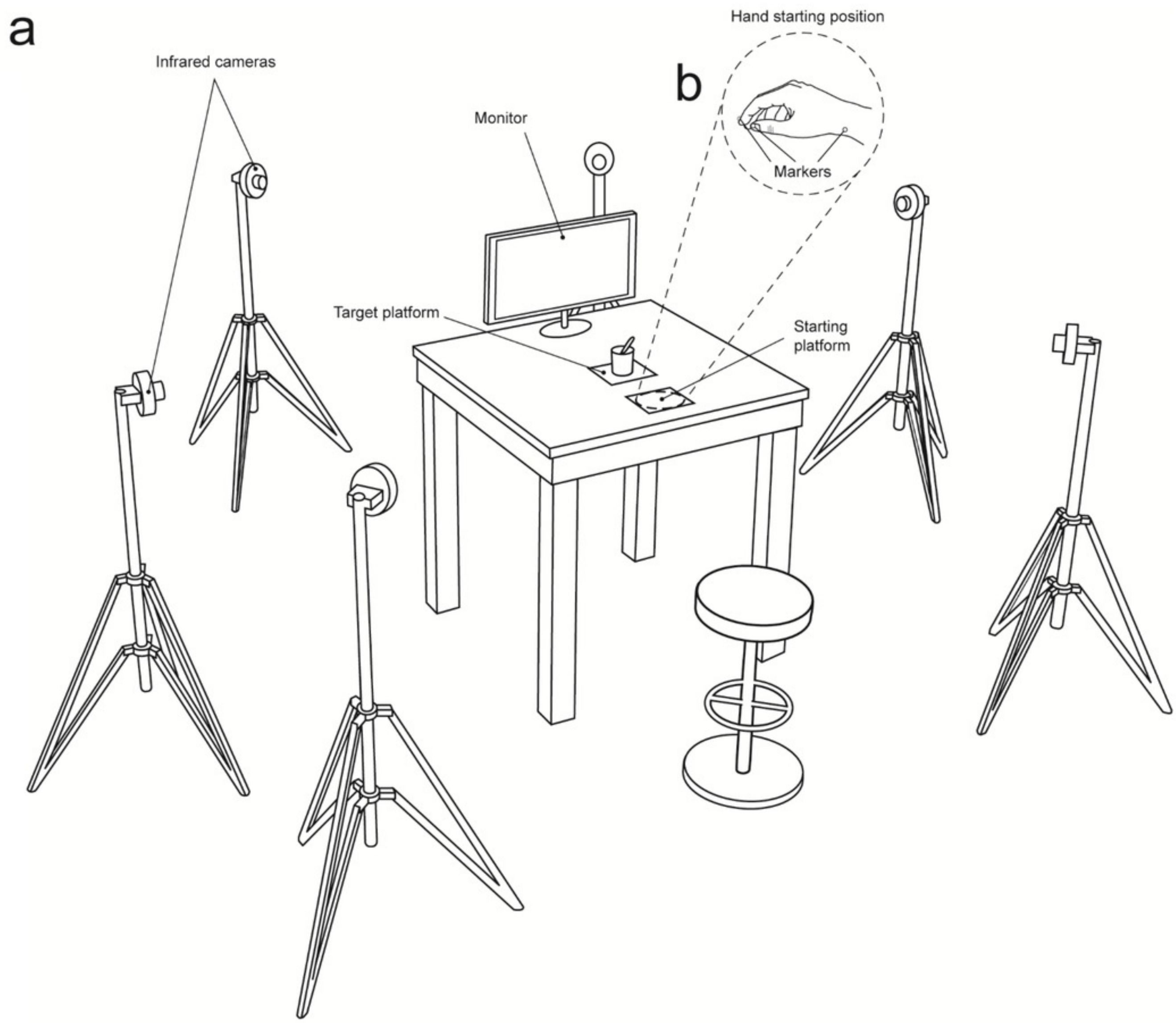
a
Infrared cameras
Monitor
b
Hand starting position
Markers
Target platform
Starting
platform

Figure 5

Results

Graphical representation of the mean values for RTs (black; a,d), MT (gray; b,e) and MGA (white; c,f) across experimental conditions (Interactive, Non-Interactive, Baseline) when participants either performed a PG (left column) or a WHG (right column). Bars represent standard error of the mean. Asterisks indicate statistically significant comparisons, (*) $p < 0.05$, (**) $p < 0.01$.