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Hitting is male, giving is female: automatic imitation and complementarity during action observation

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Abstract
Is somebody going to hurt us? We draw back. The present study investigates using behavioral measures the interplay between imitative and complementary actions activated while observing female/male hands performing different actions. Female and male participants were required to discriminate the gender of biologically and artificially colored hands that displayed both individual (grasping) and social (giving and punching) actions. Biological hands evoked automatic imitation, while hands of different gender activated complementary mechanisms. Furthermore, responses reflected gender stereotypes: giving actions were more associated to females, punching actions to males. Results have implications for studies on social stereotyping, and for research on action observation, showing that the mirror neuron system resonates in both an imitative and complementary fashion.

Keywords: automatic imitation, complementary effect, action observation, gender

Introduction

The ability to respond adequately to the actions of others underscores any form of social interaction between humans. Depending of the others who are in front of us and of the kind of action we observe, we might decide how to react.

Two basic processes have been identified, underlying action observation. Both processes are mediated by the mirror neuron system (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; for a review, see Rizzolatti & Craighero, 2004).

The first is the process of motor resonance or automatic imitation, and it indicates that our brain responds (resonates) more the higher the similarity between the actions we observe and those that are part of our motor repertoire. For example, an fMRI study showed that the human mirror neuron system responds to monkeys biting objects, but not to dogs barking, since barking is not an action humans are able to perform (Buccino et al., 2001). Further work demonstrated with basketball athletes how the capacity to anticipate and predict others' actions through motor resonance is modulated by the motor expertise (Aglioti, Cesari, Romani, & Urgesi, 2008). Motor resonance is higher the more we are familiar with the gestures we observe, also for cultural reasons. Molnar-Szakacs et al. (Molnar-Szakacs, Wu, Robles, & Iacoboni, 2007) showed with TMS a higher corticospinal excitability during observation of culture-specific emblems: Euro-American participants resonated more to hand gestures of an Euro-American actor, Nicaraguan participants to gestures of a Nicaraguan actor.

The second process occurs when the mirror neuron system does not resonate to actions that are similar to our own but instead to actions that are complementary to our own actions. Is somebody going to caress us? We prepare ourselves, leaning forward toward the other person. Is somebody going to hurt us? We draw back. In recent studies action complementarity has been investigated mainly by means of fMRI and TMS techniques (e.g., Newman-Norlund, van Schie, van Zuijlen, & Bekkering, 2007; Sartori, Cavallo, Bucchioni, & Castiello, 2012; for a review see Hamilton 2013). For example, Newman-Norlund and colleagues (2007) conducted an fMRI study in which participants were asked either to imitate or to perform a complementary action to power and precision grips with a manipulandum. They demonstrated not only that, depending of the context, the mirror neuron system can be activated for both imitative and complementary actions; but also that, compared to imitative actions, complementary actions determine an increased activation of the mirror neuron system (for a more cautious position see Ocampo, Kritikos, & Cunnington, 2011). Sartori et al. (Sartori, Bucchioni, & Castiello, 2013) found with a study with transcranial magnetic stimulation (TMS) that the motor system can shift quite early from imitative to complementary action, in order to anticipate future actions and to prepare possible responses.

Although some recent studies have greatly extended our knowledge about imitative and complementary actions, the majority of them investigated the neural underpinnings of such actions, employing TMS or brain imaging techniques. Furthermore, they typically make use of stimuli consisting of actions performed on objects.

While there are a number of TMS and brain imaging studies on motor resonance, to our knowledge behavioral studies focusing on this issue are not many. Some recent behavioral studies[1] have demonstrated the activation of motor resonance using images of hands suggesting potential actions as stimuli (see also Ellis et al., 2013). Ranzini and colleagues (2011) provided evidence of higher

[1] Notice that, in behavioral tasks, the presence of motor resonance can be inferred but not directly established, since the mirror system activation is not directly measured. Likely due to this reason, the authors of many behavioral studies prefer to avoid using the term "motor resonance", and use instead "congruent action mapping", "automatic imitation", "motor facilitation following observation of identical actions" or other formulations (Hamilton, 2013; Ocampo & Kriticos, 2010). Here we will use the term "automatic imitation", even if this is inconsistent with our previous work (e.g., Anelli, Borghi, & Nicoletti, 2012; Liuzza, Setti, & Borghi, 2012; Ranzini, Borghi, & Nicoletti, 2011), due to the possible limitations of the use of "motor resonance" in the context of a behavioral study (see Heyes, 2010; see also Brass, Bekkering, Wohlschläger, & Prinz 2000; Brass, Bekkering, & Prinz, 2001).

motor resonance to human than to robotics and fake hands with a line bisection paradigm. Liuzza et al. (2012) asked children to categorize the weight (light vs. heavy) of target-objects preceded by children and adult hand-primes in a grasping or control posture. Response times were recorded while children pressed two different keys on the key-board. Children grasping hand-primes elicited the fastest responses: this indicate that children resonate more to other children's hands, hence that motor resonance is higher in presence of individuals endowed with a body schema similar to ours.

Even if the last two studies provide evidence of motor resonance (from now on automatic imitation) at a behavioral level, in the first the effect was due to the difference between biological and robotics hands, in the second to hands belonging to organisms with a different body schema, i.e. children and adults. In both studies grasping actions were used, and in none of them complementary mechanisms emerged.

In the present study we intend to investigate how observing hands of others activate the processes of automatic imitation and complementarity, and to analyze the interplay between these two mechanisms (Faber, van Elk, & Jonas, 2016). Participants saw a natural or artificially red-colored female/male hand performing three different actions: giving, grasping, and punching. Thus, we manipulated the following factors: a. Hands' biological character (biological vs. artificially-colored hands), b. hands' gender (same vs. different from participant's gender), c. actions performed by hands (individual vs. social actions). With individual action we intend an action typically directed toward an object, such as grasping, while with social actions we intend an action directed toward the other with the intent to engage in a social interaction, such as giving and punching.

The task required to determine the hand gender. Specifically, in Experiment 1 participants were instructed to press two different keys on the keyboard, while in Experiment 2 they had to press two different keys moving their arm toward or away from their own body to provide the response. We focused on rather coarse automatic imitation and complementary mechanisms rather than on fine-grained ones. Participants were indeed not required to perform actions responding to the observed ones, e.g. to grasp an object in response to the giving actions. They were instead required to simply press a key or to perform movements toward or away from their own body in response to actions performed without a specific object.

In line with behavioral evidence on automatic imitation, responses to natural hands should be faster than responses to artificially red-colored hands, because of their similarity with our own effectors. Aside from the activation of automatic imitation mechanism, we also predict that complementary mechanisms should play a major role when focusing on more specific distinctions, such as the distinction between hands of different gender and that between hands displaying different kinds of actions. This hypothesis is consistent with recent behavioral (e.g., Ocampo & Kriticos, 2010; van Schie, van Waterschoot, & Bekkering, 2008) and neural (e.g., Sartori et al., 2013) findings demonstrating that action observation could directly prime motor activation for complementary actions, rather than for imitative ones.

Specifically, we intend to test whether information on gender and/or information on the kind of action influences the toward the responses in a complementary fashion. Notice that information on gender is not only perceptual, since each gender is typically associated with specific kinds of action. It is possible that gender stereotypes such as those linking males to more aggressive behaviors and females to more altruistic behaviors are at work (Frodi, Macaulay, & Thome, 1977; Carlo, Raffaelli, Laible, & Meyer, 1999; Harris & Siebel,1975), and that they influence action preparation in response to actions of others. If information on gender plays a major role in determining complementary actions, females should respond faster to male hands, as a consequence of the negative stereotype linking males to aggressive behavior, independently from the performed action. If both gender and kind of action play a role, then such an effect should be stronger with social actions, in particular for punching actions.

Experiment 1

Method

Participants. Twenty-four (12 females, age range: 19 – 24 years) volunteer students of the University of Bologna participated. All participants had normal or corrected-to-normal vision, and were not aware of the purpose of the experiment. The study was approved by the Psychology Department's ethical committee of the University of Bologna. Participants gave written informed consent to participate in this study.

Apparatus and stimuli. The experiment took place in a dimly lit and noiseless room. Participants were seated facing a 17" cathode-ray tube screen driven by a 700 MHz computer. The participant's head was positioned in an adjustable head-and-chin rest. Stimulus selection, response timing, and data collection were controlled by the E-Prime 1.1 software. A fixation cross (0.95° X 0.95° of visual angle) was presented at the beginning of each trial.

Stimuli were digital photographs of 384 human hands at their actual size: 24 different human hands (12 female and 12 male hands) x 4 postures (one open hand and three mimicking give/grasp/punch postures hand, respectively) x 2 positions (allocentric/egocentric) x 2 colors (natural/red). A rating test was performed on the stimuli to assess whether participants could be able to identify correctly the action as grasping/giving and punching (see the Appendix for detail). The colored red versions of each hand was created using Gimp Software (2.5 version). We decided to use red-colored hands to signal their unnatural character. The hands in the open position, both red and natural-colored, served as primes before target pictures in order to create the perception of movement. Furthermore, we used images of hands suggesting a potential action instead of videos since previous TMS evidence revealed that observation of static hands suggesting a grasping action lead to an increased corticospinal excitability when compared to both static hands and hand postures suggesting a complete action (Urgesi, Moro, Candidi, & Aglioti, 2006).

Procedure. Each trial began with the fixation cross presented in the center of the screen for 250 milliseconds (ms). In order to create the perception of movement, the open hand was displayed at the center of the screen for 50 ms, followed by one of the three types of randomly intermixed hands mimicking the give/grasp/punch postures, which remained on the screen until a response was made or until 1500 ms have passed. The feedback GIUSTO (i.e. correct) or ERRORE (i.e., error) or NON HAI RISPOSTO (i.e., no answer was emitted) was given for correct, incorrect or delayed responses, respectively, and remained on the screen for 1500 ms. The task required participants to discriminate the gender of the hand mimicking the give/grasp/punch postures. Participants were tested individually in a single session, which comprised 2 blocks. In the first block, which was composed by 48 practice trials followed by 144 experimental trials (6 for each stimulus), participants had to press the "b" button with the left index finger for the female hand and the "n" button with the right index finger for the male hand. In the second block the button assignments were reversed and for this reason the practice trials were increased to 60 trials while the number of the following experimental trials was the same as in the first block. The order of the two blocks was counterbalanced across participants. In this context we intend a faster button press response to a hand of the same gender and a slower response to the hand of a different gender as indication of gender-based automatic imitation, the opposite mapping as a signal of gender-based complementarity.

In total, the Experiment was composed of 396 experimental trials, since 12 repeated stimuli were added to the training of the second block. The instructions stressed both the speed and accuracy of response. Participants were allowed to take a short break between blocks. For a schematic example of the procedure and the response set see Figure 1.

******Please insert Figure 1 here******

Results

Trials for which the RTs were more than two standard deviations smaller (0.07%) or greater (4.4%)

than the participant's overall mean RT were excluded from the analysis. Incorrect responses (12%) were also discarded. Analysis of errors revealed no evidence of a speed–accuracy trade-off, so we focused on RT analysis.

Mean correct RTs was submitted to a mixed ANOVA with *Color* (natural *vs.* red), *Hand gender* (female *vs.* male) and *Posture* (give *vs.* grasp *vs.* punch) as within-subject factors, and *Participant's gender* (female *vs.* male) as between-subjects factor. Fisher's LSD post-hoc tests were also conducted on significant interactions.

For RTs the main effect of *Color* was significant, $F(1,22) = 14.82$, $MSe = 779.16$, $p = .001$, $\eta_p^2 = .40$. Responses to natural hands (M = 509 ms) were faster than responses to red hands (M = 521 ms). The main effect of *Posture* was also significant, $F(2,44) = 20.68$, $MSe = 454.98$, $p < .001$, $\eta_p^2 = .48$. The post-hoc test showed that responses to the give posture were significantly slower than responses to the grasp and punch postures (M = 526 *vs.*509 and 510 ms, respectively), $p_s < .001$.

The interaction between *Hand gender* and *Color* factors was significant, $F(1,22) = 8.73$, $MSe = 805.41$, $p = .007$, $\eta_p^2 = .28$. The post hoc test showed that when stimuli were colored as natural, responses to the female hands were the fastest overall, $p_s < .05$, see Table 1 (top panel).

The interaction between *Hand gender* and *Posture* factors was significant, $F(2,44) = 15.56$, $MSe = 1707.07$, $p < .001$, $\eta_p^2 = .41$. The post hoc test showed that for the give posture responses to the male hand (M = 543 ms) were slower than ones to the female hand (M = 510 ms), $p < .001$, whereas responses to the grasp posture did not reveal any differences (M = 511 vs. 506 ms, for male and female hand, respectively, $p = .51$). Furthermore, for the punch posture responses to the male hand (M = 493 ms) were faster than ones to the female hand (M = 526 ms), $p < .001$, and the fastest overall, $p_s < .05$, see Table 1 (middle panel).

The interaction between *Hand gender* and *Participant's gender* factors was significant, $F(1,22) = 10.08$, $MSe = 1353.52$, $p = .004$, $\eta_p^2 = .31$. The post hoc test showed that female participants' responded faster to the male hand (M = 521 ms) than to the female one (M = 533 ms), $p = .06$; furthermore, male participants' responded faster to the female hand (M = 495 ms) than to the male one (M = 511 ms), $p = .02$, see Table 1 (bottom panel) and Figure 2.

No others significant main effect or interactions were found, $F_s < 2.5$.

******Please insert Table 1 and Figure 2 here******

Discussion

Results of Experiment 1 confirm our initial prediction on automatic imitation: naturally colored hands are indeed responded faster than red-colored ones. The *Color* main effect is qualified by the *Color* x *Hand gender* interaction, showing that female natural hands are the fastest to be responded to. This result is probably due to perceptual reasons, and it is theoretically less important for us.

As to *Posture*, the fact that giving postures are slower than punching and grasping actions reveals the presence of action-based complementarity effect: in line with current kinematics literature (Ferri, Campione, Dalla Volta, Gianelli, & Gentilucci, 2010; Gianelli, Lugli, Baroni, Nicoletti, & Borghi, 2013; Sartori, Cavallo, Bucchioni, & Castiello, 2012), actions in which an agent and a recipient interact are slower, since both agents have to adapt and adjust to each other. While this accuracy effect is well known in kinematics literature, to our knowledge it is the first time in which it is found in a behavioral task in which no online interaction occurs. Furthermore, to our knowledge it was found only in positive social action; here we extend our knowledge of such effect since we find that it is present in positive social actions but not in negative ones (punching actions are processed slower than giving actions).

Crucially, we also found gender-based complementarity effects: female responses were faster with male hands, and male hands were faster with female hands.

Finally, we found that response times were modulated by the kind of action, and that results on social actions (giving, punching) reflected social stereotypes: for giving actions male hands were processed slower than female ones, while the mapping was opposite for punching actions; finally, no difference was present between the genders for grasping actions.

Experiment 2

Experiment 2 was designed in order to test whether the effects found in Experiment 1 were confirmed with an approach-avoidance paradigm, in which participants are invited to perform movements toward or away from the body to respond. The toward or away from the body kind of movements to respond is common with linguistic stimuli, as the evidence on the approach-avoidance effects shows (Chen & Bargh, 1999; Lugli, Baroni, Gianelli, Borghi, & Nicoletti, 2012; Seibt, Neumann, Nussinson, & Strack, 2008; Topolinkski, Maschmann, Pecher, Winkielman, 2014; van Dantzig, Pecher, & Zwaan, 2008). Approach-avoidance effects were found with emotionally connoted stimuli: people are typically faster to attract positive objects toward themselves and to push negative objects away. Importantly, approach-avoidance effects were found also in interactive contexts with non-linguistic stimuli (Scorolli, Miatton, Wheaton, & Borghi, 2014; for a meta-analysis see Phaf, Mohr, Rotteveel, & Wicherts, 2014).

Specifically, we predict to confirm previous results of Experiment 1 and to find that gender-based complementary effects modulate the movement direction while responding. Would a female react to a male hand giving something to her with an away from the body movement response, as the giving action typically implies, or withdrawing from it, due to the association of the male gender with aggressive behaviors? In this context we intend a movement toward the body and away from the screen as a signal of complementarity; in contrast, we intend a movement away from the body and toward the screen as the mirror reproduction of the seen action, hence as a signal of automatic imitation.

Method

Participants. Twenty-four (12 females, 3 left handed) with a mean age of 23.5 years (female mean: 22.7, male mean: 24.3) volunteer students of the University of Bologna participated. All participants had normal or corrected-to-normal vision, and were not aware of the purpose of the experiment.

The experiment was approved by the Psychology Department’s ethical committee of the University of Bologna. Written informed consent was obtained from all individual participants included in the study.

Apparatus, stimuli and procedure. Apparatus, stimuli and procedure were the same as in Experiment 1, whereas the participants’ responses varied as follows. A modified keyboard with only the space bar and two oversized buttons was used. The keyboard was turned lengthwise, with the narrow part facing the participant so that one button was toward the participant’s body and the other was away from the participant’s body and closer to the computer screen; the space bar was between the two buttons. Participants were asked to discriminate the gender of the hand mimicking the give/grasp/punch postures by hitting the corresponding button with their dominant hand open. RTs were measured from the release of the spacebar to the button press. In the first block participants were required to press the toward the body button for female hand and the away from the body button for male hand. In the second block the button assignments were reversed and for this reason the practice trials were increased to 60 trials. The order of the blocks was counterbalanced across participants. For a schematic example of the procedure and the response set see Figure 1. Participants were not free to choose the response direction, but were kindly recommended to follow the instructions.

Results

Trials for which the RTs were more than two standard deviations smaller (0.17%) or greater (4.5%) than the participant’s overall mean RT were excluded from the analysis. Incorrect responses (8.9%) were also discarded. Analysis of errors revealed no evidence of a speed–accuracy trade-off, so we focused on RT analysis.

Mean correct RTs was submitted to a mixed ANOVA with *Color* (natural *vs.* red), *Movement* (toward the body *vs.* away from the body), *Hand gender* (female *vs.* male) and *Posture* (give *vs.* grasp *vs.* punch) as within-subject factors, and *Participant's gender* (female *vs.* male) as between-subjects factor. Fisher's LSD post-hoc tests were also conducted on significant interactions.

For RTs the main effect of *Color* was significant, $F(1,22) = 6.49$, $MSe = 767.75$, $p = .018$, $\eta_p^2 = .23$. Responses to natural hands (M = 653 ms) were faster than responses to red hands (M= 659 ms). In addition, the main effect of *Posture* was significant, $F(2,44) = 3.84$, $MSe = 1706.68$, $p = .03$, $\eta_p^2 = .15$. The post-hoc test showed that responses to the give posture (M = 662 ms) tended to be slower than those to the grasp posture (M= 654 ms), $p = .06$, and were significantly slower than responses to the punch posture (M = 651 ms), $p = .01$.

The interaction between *Hand gender* and *Posture* factors was significant, $F(2,44) = 11.62$, $MSe = 1308.04$, $p < .001$, $\eta_p^2 = .35$. The post hoc test showed that for the give posture responses to the male hand (M = 668 ms) were slower than ones to the female hand (M = 657 ms), $p = .04$. Conversely, for the grasp posture responses to the male hand (M = 649 ms) were faster than responses to the female hand (M = 660 ms), $p = .05$. Furthermore, for the punch posture responses to the male hand (M = 639 ms) were faster than responses to the female hand (M = 663 ms), $p < .001$, and the fastest overall, $p_s < .05$, see Table 2 (top panel).

The interaction between *Participant's gender*, *Hand gender* and *Color* factors was significant, $F(1,22) = 7.21$, $MSe = 1170.42$, $p = .01$, $\eta_p^2 = .25$. The post hoc test showed that female participants' responses to the male hand were faster than responses to the female one, both natural and red colored (M = 642 and 642 ms *vs*. 659 and 668 ms, respectively, $p_s < .05$), while male participants' responses to the female hand were faster than to the male one only when it was red colored (M = 654 and 671, respectively, $p = .01$). Furthermore, male participants' responses to the male hand were faster when natural than red colored (M = 652 *vs*. 671 ms, respectively, $p < .001$), see Table 2 (middle panel).

The interaction between *Participant's gender*, *Hand gender* and *Movement* factors was significant, $F(1,22) = 12.16$, $MSe = 9365.80$, $p = .002$, $\eta_p^2 = .36$. The post hoc test showed that female participants' responses to the female hand were faster with the away from the body movement than the toward the body one (M = 643 *vs*. 684 ms, respectively, $p = .02$), whereas female participants' responses to the male hand were faster with the toward the body movement than the away from the body one (M = 623 *vs*. 662 ms, respectively, $p =.03$). Furthermore, when female participants responded with the toward the body movement, RTs to the male hand where faster than to the female hand (M = 623 *vs*. 684 ms, respectively, $p < .001$). Male participants' responses to the male hand were faster with the away from the body movement than the toward the body one (M = 644 vs. 679 ms, respectively, $p = .04$), see Table 2 (bottom panel) and Figure 3.

No others significant main effect or interactions were found, $F_s < 3.8$.

******Please insert Table 2 and Figure 3 here******

Starting from the results of the female participants that performed movements to withdraw their own hand from the male hand, two different Questionnaires in order to enhance further the social aspects, that is to better understand if this matching effect is correlated with gender attitudes, were run.

26 raters (13 female and 13 male) were tested individually and were instructed to perform two different Questionnaires. The first concerned the evaluation of the images presented in both Experiment 1 and 2. Participants were required to evaluate on a seven-point Likert scale (with 1 = masculine and 7 = feminine) how intensely the 3 different postures were conveyed by the male/female hand targets. The second concerned the evaluation of 60 words (taken from Rudman, Greenwald & McGhee, 2001): 15 potent-meaning words (e.g., power, strong, bold), 15 weak-

meaning words (e.g., weak, vulnerable, timid), 15 warm-meaning words (e.g., warm, support, nurture) and 15 cold-meaning words (e.g., cold, distant, detached). Participants were required to evaluate on a seven-point Likert scale (with 1 = only for male and 7 = only for female) to what extend the words presented can only be true for men or for women.

For both female and male participants separately, a Pearson product-moment correlation coefficient was computed to assess the relationship between the rating on the images presented in both Experiment 1 and 2 and the rating of the potent/weak/warm/cold words.

As regard male participants, results showed a moderate positive correlation between the cold words and the female hand with both the give ($r = 0.54$, $n = 13$, $p = .054$), and the grasp posture ($r = 0.56$, $n = 13$, $p = .048$). Crucially, as regard female participants, results showed a strong negative correlation between the male hand with the punch posture and the warm words ($r = -0.64$, $n = 13$, $p = .018$). This strong negative relationship suggests that viewing a punch by a hand male corresponded to also viewing male gender as cold.

Discussion

Results of Experiment 2 confirm and extend those of Experiment 1. The advantage of natural over red-colored hands, likely due to automatic imitation, is confirmed. However, the *Color* main effect is qualified by the interaction between *Color*, *Hand gender* and *Participant's gender* factors, and is therefore complicated by the presence of complementary mechanisms. Female participants responded indeed faster to male hands, independently from their being natural or artificial. As to males, in line with the automatic imitation hypothesis they responded faster to male natural than to male artificial hands, but they did not provide evidence of complementary mechanisms as they did not show an advantage in processing female hands. This suggests that, differently than for males, for females gender-based complementary mechanisms overcome automatic imitation mechanisms. We also replicated the finding that giving hand postures were slower than punching hand postures, supporting the idea that positive social action are typically performed more carefully and accurately. In addition, the interaction between *Hand gender* and *Posture* factors confirmed that actions are interpreted in the framework of social stereotypes, since giving hand postures are more associated to females, punching hand postures to males. The presence of such stereotypes was confirmed by the correlations we performed: in particular, for females we found a negative correlation between the punch posture of males and warm words, while for males we found that give and grasp actions performed by females were correlated with cold words.

Finally, we found that the gender-based complementarity effect found in Experiment 1 was modulated by approach-avoidance movements. As predicted, females automatically imitated more females and males imitated more males (they were faster in performing movement away from the body and toward the screen reproducing the observed action), while females, but not males, used more complementary mechanisms with males (they were faster in performing movements toward the body and away from the screen). The correlations we found help in qualifying this kind of complementarity: both genders perceive actions performed by the other gender as positively associated to cold words or as negatively correlated to warm words. One could speculate that this complementarity is generated by mutual distrust; the distrust is particularly pronounced by females with respect to males.

General Discussion

The results of the present study confirm the majority of our hypotheses. We will first illustrate and interpret the main results, then discuss their possible implications for current literature.

First, we found the predicted effect of overall automatic imitation, revealed by the faster responses with the natural compared to the artificially-colored hand. We tend to exclude that the effect is simply due to familiarity, also in light of other results in the literature. Avenanti, Sirigu and Aglioti (2010) investigated empathic reactivity to white and black hands with a TMS; they found an advantage of a biological hand belonging to the in-group over an artificially colored (violet) hand, but also an advantage of the unfamiliar artificially colored hand over a hand belonging to the out-group. We also tend to exclude that the effect is due to the fact that it is easier to discriminate hand gender for naturally colored hands than for red colored hands, or that the effect is due to some low level perceptual phenomena, due for example to differences in brightness. This account would not clearly explain the interaction we found between *Hand gender* and *Color* in Experiment 1 and in particular the interaction between *Participant's gender, Hand gender* and *Color* factors in Experiment 2. Female participants responded indeed faster to male hands, independently from their being natural or artificial. As to males, in line with the automatic imitation hypothesis they responded faster to male natural than to male artificial hands, but they did not show an advantage in processing female hands, thus no evidence of complementary mechanisms was provided. This suggests that for females gender-based complementary mechanisms overcome automatic imitation mechanisms, while this is not true for males. At a theoretical level, the result we illustrated is consistent with theories proposing the existence of a common coding between action observation and action execution: the higher the similarity between perceived events and actions to perform, the easier action identification and processing is (Prinz, 1997; Hommel, Musseler, Aschersleben, & Prinz, 2001).

Second, and more crucial, results provide evidence of complementary mechanisms while observing actions of hands of the other gender. As predicted, we found an interaction between *Participant's gender*, *Hand gender* and *Movement* factors. Female participants performed movements away from hands of the opposite gender. We interpret female movements as defense movements, that is movements performed to withdraw their own hand from a potential threatening stimulus, the male hand. Previous studies have indeed revealed that participants with empty hands reach positive objects which are far from them and reject negative objects which are close to them (Freina, Baroni, Borghi, & Nicoletti, 2009). The correlations we found confirm that in females male punching actions are negatively correlated with warm words. There could be different reason why we found a "defense" behavior in females and no specular effect in males. First, females are more sensitive than males to social stimuli (Deaner, Shepherd, & Platt, 2007; see also Geary, 2010 for a review) linked to direct interaction: for example gaze cueing effects are stronger in females than in males (Bayliss, Di Pellegrino, & Tipper, 2005). Second, negative emotions, as those that can ground defense behavior, are typically more salient than positive ones (e.g., Maratos, Mogg, & Bradley, 2008; Öhman, Lundqvist, & Esteves, 2001).The reason why we found complementary rather than imitation mechanisms at work might have been enhanced by the actions we presented. However, this does not seem to be the case since, contrary to our predictions, we did not find that the effect was more marked with punching compared to giving and grasping.

As far as the kinds of action are concerned, we found two unexpected results that are worth mentioning.

First, we found that the giving action evoked slower responses than both the punching and the grasping one. Even if we did not predict this effect, our finding is in line with kinematics evidence (Becchio, Sartori, Bulgheroni, & Castiello, 2008; Ferri et al., , 2010; Gianelliet al., 2013) revealing a high accuracy in social actions, due to the necessity to adapt our actions to the other. This accuracy, consistently with other results, characterizes a positively connoted social action such as giving, not a negative one, such as punching, that requires a fast withdrawal movement. This result further testifies the presence of complementarity mechanisms: since the giving response implies a positive interaction with another person, more attention and higher accuracy is devoted in programming the action. The slower RTs (likely due to higher accuracy) we found in responding to giving hands can be read in terms of the notion of readiness to interact (Di Paolo & Jaegher, 2012), that is a disposition to engage in social interactions at different levels, from responding to social stimuli to being involved in real social interactions. Our results clearly show that readiness to interact with images is modulated by the kind of presented action, as the difference between giving

and punching testifies.
Second, we found that punching actions were processed faster when executed by males, while giving actions were processed faster when performed by females. These associations reflect the stereotype of a higher aggressiveness of males corresponding to higher altruism in females (Eagly & Steffen, 1986). These stereotypes are likely shared by the entire sample, as suggested by the absence of an interaction with participants' gender. However, our correlations revealed that males tended to associate the actions of giving and grasping performed by females to cold words, while females associated the action of punching performed by males with the opposite of warm words.
Overall, our results have implications for research on automatic imitation and its neural basis: they indeed suggest that for broad distinctions as that between biological and artificially colored hands, a mechanism of motor resonance is active. In contrast, for more specific distinctions, such as that between male and female gender, the mirror neuron system might be more activated for complementary actions. Importantly, if we consider the actions independently from the agent performing them, a giving action would be complemented by away from the body response, while a punching action would be complemented by a toward the body movement. However, our results are intriguing because, when participants' gender differs, females tend to withdraw (moving toward their own body) as soon as they see an action performed by a male, independently of its positive vs. negative connotation. Approach and avoidance is thus influenced mostly by information on the agents gender. We exclude that this is due to the fact that differences between actions were not processed, because response times differ depending on the kind of action.
To our knowledge, the present is the first study that considers the role of gender in the interplay between automatic imitation and activation of complementary actions. The fact that hands differing in gender activate complementarity mechanisms might appear in contrast with evidence on gender-based automatic imitation. However, carefully scrutinizing the literature we found it is not. To our knowledge only two studies have shown gender-based resonance effects (see also Cheng et al., 2008; 2009). Calvo-Merino et al. (Calvo-Merino, Grèzes, Glaser, Passingham, & Haggard, 2006) performed an fMRI study on female and male dancers. Both genders are familiar with all ballet moves, since they train together. However, some moves are performed only by female or by male dancers. When dancers observed videos of gender-specific moves, results showed gender specific automatic imitation effects, i.e. greater premotor, parietal, and cerebellar activity. Even if the effect pertains gender, it is likely due to the fact that gender-specific movements were used, thus people of each gender resonated more to the kind of movements they were able to perform. In sum, the take home message of the study is more "you resonate more to actions you are able to perform" than "you resonate more to actions performed by people of your own gender". In a behavioral study Anelli et al. (2012) asked adults and children to observe images of robotics hands and of human male and female hands followed by graspable neutral and dangerous objects (e.g., tomato vs. cactus); their task consisted in categorizing the target-objects into artifacts/natural objects. All participants responded faster to human than to robotics hands, revealing a general motor resonance mechanism. Specific automatic imitation mechanisms related to the gender of the hand emerged instead only in male adults: males responses to male grasping hands were the fastest. However, only static and grasping hands were shown, followed by objects; the difference with the present study can be due to the priming task, in particular to the presence of a target object, as well as to the introduction in the present work of social actions differing in valence. In addition, importantly no automatic imitation effect in females was found, thus confirming our results, in which in females a complementarity mechanism was active. A further note: in the present study we presented transitive actions without an object. Our findings clearly extend previous results, as they suggests that images of hands displaying potential actions (Urgesi et al., 2006) can evoke both automatic imitation and complementarity mechanisms even in absence of the object toward which the action is directed.
The final unexpected result, the association between punching actions with males, and giving actions with females, has implication for current literature on social stereotyping. Our method

allowed us to detect implicit stereotypes and to investigate how they are transformed in forms of action preparation. Studies with tasks that do not require to discriminate gender can further shed light on these issues. Further research is needed to investigate in depth how our interpretation of others' actions reflects our implicit biases and willingness or not to interact.

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Ethical approval

All procedures performed in this study involving human participants were in accordance with the ethical standards of the Psychology Department's ethical committee of the University of Bologna and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

References

Aglioti, S. M., Cesari, P., Romani, M., & Urgesi, C. (2008). Action anticipation and motor resonance in elite basketball players. *Nature Neuroscience*, *11(9)*,1109–1116.

Anelli, F., Borghi, A.M., & Nicoletti, R. (2012). Grasping the pain: Motor resonance with dangerous affordances. *Consciousness and Cognition*, *21*, 1627–1639.

Avenanti, A., Sirigu, A., & Aglioti, S. M. (2010). Racial bias reduces empathic sensorimotor resonance with other-race pain. *Current Biology*, *20*, 1018–1022.

Bayliss, A .P., Di Pellegrino, G.D., & Tipper, S.P. (2005). Sex differences in eye gaze and symbolic cueing of attention. *Quarterly Journal of Experimental Psychology*, 58, 631 – 650.

Becchio, C., Sartori, L., Bulgheroni, M., & Castiello, U. (2008) Both your intention and mine are reflected in the kinematics of my reach-to-grasp movement. *Cognition*, *106(2)*, 894–912.

Brass, M., Bekkering, H., & Prinz, W. (2001). Movement observation affects movement execution in a simple response task. *Acta Psychologica*, 106, 3 – 22.

Brass, M., Bekkering, H., Wohlschläger, A., & Prinz, W. (2000). Compatibility between observed and executed finger movements: comparing symbolic, spatial, and imitative cues. *Brain & Cognition*, 44, 124 – 143.

Buccino, G., Binkofski, F., Fink, G. R., Fadiga, L., Fogassi, L., Gallese, V., Seitz, R.J., Zilles, K., Rizzolatti, G., & Freund, H-J. (2001). Action observation activates premotor and parietal areas in a somatotopic manner: An fMRI study. *European Journal of Neuroscience*, *13(2)*, 400–404.

Calvo-Merino, B., Grèzes, J., Glaser, D. E., Passingham, R. E., & Haggard, P. (2006). Seeing or doing? Influence of visual and motor familiarity in action observation. *Current Biology*, *16(19)*, 1905–1910.

Carlo, G., Raffaelli, M., Laible, D. J., & Meyer, K. A. (1999). Why are girls less physically aggressive than boys? Personality and parenting mediators of physical aggression. *Sex Roles*, *40*, 711-729.

Chen, M., & Bargh, J. A. (1999). Consequences of automatic evaluation: Immediate behavioral predispositions to approach or avoid the stimulus. *Personality and Social Psychology Bulletin*, *25*, 215–224.

Cheng, Y., Chou,K.-H., Decety, J., Chen, I.-Y., Hung, D., Tzeng, O. J.-L. & Lin, C.-P. (2009). Sex differences in the neuroanatomy of human mirror neuron system: a voxel-based morphometric investigation. *Neuroscience*, *158*, 713–720.

Cheng, Y., Lee, P.-L., Yang, C.-Y., Lin., C.-P., Hung, D., & Decety, J. (2008). Gender Differences in the Mu Rhythm of the Human Mirror-Neuron System. *PLoS ONE*, *3(5)*, e2113. doi:10.1371/journal.pone.0002113.

Deaner, R.O., Shepherd, S.V., & Platt, M.L. (2007). Familiarity accentuates gaze cuing in women but not men. *Biology Letters*, 3, 64–67.

Di Paolo, E., & De Jaegher, H. (2012). The interactive brain hypothesis. *Frontiers in Human Neuroscience* 6(163): doi:10.3389/fnhum.2012.00163.

Eagly, A.H., & Steffen, V.J. (1986). Gender stereotypes stem from the distribution of women and men into social roles. *Journal or Personality and Social Psychology*, *46(4)*, 735–754.

Ellis, R., Swabey, D., Bridgeman, J., May, B., Tucker, M., & Hyne, A. (2013). Bodies and other visual objects: the dialectics of reaching toward objects. *Psychological Research*, *77*, 31–39.

Faber, T.W., van Elk, M., & Jonas, K.J. (2016). Complementary hand responses occur in both peri- and extrapersonal space. *PLoS ONE*, 11(4): e0154457. doi:10.1371/journal.pone.0154457

Ferri, F., Campione, G.C., Dalla Volta, R., Gianelli, C., & Gentilucci, M. (2010). To me or to you? When the self is advantaged. *Experimental Brain Research*, *203*, 637–646.

Freina, L., Baroni, G., Borghi, A.M., & Nicoletti, R. (2009). Emotive concept-nouns and motor responses: Attraction or repulsion? *Memory & Cognition*, *37*, 493–499.

Frodi, A., Macaulay, J., & Thome, P.R. (1977). Are women always less aggressive than men? A review of the experimental literature. *Psychological Bulletin*, *84*, 634-660.
Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain*, *119*, 593–609.
Geary, D.C. (2010). *Male, female: The evolution of human sex differences* (2nd edition). Washington, DC: American Psychological Association.
Gianelli, C., Lugli, L., Baroni, G., Nicoletti, R., & Borghi, A.M. (2013). The Impact of Social Context and Language Comprehension on Behaviour: A Kinematic Investigation. *PLoS ONE*, *8(12)*, e85151. doi:10.1371/journal.pone.0085151.
Hamilton, A.F. de C. (2013) The mirror neuron system contributes to social responding. *Cortex* 49: 2957 – 2959.
Harris, M.B., & Siebel, C.E. (1975). Affect, aggression, and altruism. *Developmental Psychology*, *11*, 623-627.
Heyes, C. (2010). Automatic imitation. *Psychological Bulletin*, 137, 463 – 483.
Hommel, B., Musseler, J., Aschersleben, G., & Prinz, W. (2001). The theory of event coding (TEC): A framework for perception and action planning. *Behavioral and Brain Sciences*, *24*, 849–878.
Liuzza, M.T., Setti, A., & Borghi, A.M. (2012). Kids observing other kids' hands: Visuomotor priming in children. *Consciousness and Cognition*, *21*, 383–392.
Lugli, L., Baroni, G., Gianelli, C., Borghi, A.M., & Nicoletti, R. (2012) Self, Others, objects: How this triadic interaction modulates our behaviour. *Memory & Cognition*, *40*, 1373–1386.
Maratos, F. A., Mogg, K., & Bradley, B. P. (2008). Identification of angry faces in the attentional blink. *Cognition & Emotion*, 22, 1340-1352.
Molnar-Szakacs, I., Wu, A. D., Robles, F. J., & Iacoboni, M. (2007). Do you see what I mean? Corticospinal excitability during observation of culture-specific gestures. *PLoS ONE*, *2(7)*, e626. doi:10.1371/journal.pone.0000626.
Newman-Norlund, R.D., van Schie, H. T., van Zuijlen, A. M. J., & Bekkering, H. (2007). The human mirror neuron system is more active during complementary compared with imitative action. *Nature Neuroscience*, *10*, 817–818.
Ocampo, B., & Kriticos, A. (2010). Placing actions in context: motor facilitation following observation of identical and non-identical manual acts. *Experimental Brain Research*, 201, 743 – 751.
Ocampo, B., Kritikos, A., & Cunnington, R. (2011). How frontoparietal brain regions mediate imitative and complementary actions: an fMRI study. *PLoSONE*, 6(10): e26945. doi:10.1371/journal.pone.0026945.
Öhman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality & Social Psychology*, 80, 381-396.
Phaf, R. H., Mohr, S. E., Rotteveel, M., & Wicherts, J. M. (2014). Approach, avoidance, and affect: a meta-analysis of approach-avoidance tendencies in manual reaction time tasks. *Frontiers in Psychology*, 5, 378. doi: 10.3389/fpsyg.2014.00378.
Prinz, W. (1997). Perception and action planning. *European Journal of Cognitive Psychology*, *9*, 129–154.
Ranzini, M., Borghi, A. M., & Nicoletti, R. (2011). With hands I do not centre! Action- and object-related effects of hand-cueing in the line bisection. *Neuropsychologia*, *49*, 2918–2928.
Rizzolatti, G., & Craighero, L. (2004). The mirror neuron system. *Annual Review of Neuroscience*, *27*, 169–192.
Sartori, L., Bucchioni, G., & Castiello, U. (2013). When emulation becomes reciprocity. *Social Cognitive & Affective Neuroscience*, 8, 662 – 669.
Sartori, L., Cavallo, A., Bucchioni, G., & Castiello, U. (2012). From simulation to reciprocity: The case of complementary actions. *Social Neuroscience*, *7*, 146–158.

Scorolli, C., Miatton, M., Wheaton, L., & Borghi, A.M. (2014). I give you a cup, I get a cup : A kinematic study on social intention. *Neuropsychologia*, 57, 196 – 204.

Seibt, B., Neumann, R., Nussinson, R., & Strack, F. (2008). Movement direction or change in distance? Self- and object-related approach-avoidance motions. *Journal of Experimental Social Psychology*, *44*, 713–720.

Topolinski, S., Maschmann, I. T., Pecher, D., & Winkielman, P. (2014). Oral approach–avoidance: Affective consequences of muscular articulation dynamics. *Journal of personality and. social psychology,* 106(6), 885.

Urgesi, C., Moro, V., Candidi, M., & Aglioti, S.M. (2006). Mapping implied body actions in the human motor system. *The Journal of Neuroscience*, 26, 7942 – 7949.

van Dantzig, S., Pecher, D., & Zwaan, R. A. (2008). Approach and avoidance as action effect. *Quarterly Journal of Experimental Psychology*, *61*, 1298–1306.

van Schie, H.T., van Waterschoot, B.M., & Bekkering, H. (2008). Understanding action beyond imitation: Reversed compatibility effects of action observation in imitation and joint action. *Journal of Experimental Psychology: Human Perception and Performance,* 34, 1493–1500.

Appendix

Thirty-five raters were tested individually with an online questionarie and were instructed to evaluate if 4 different human hands (2 female/2 male identities) x 3 postures (give/grasp/punch) x 2 positions (allocentric/egocentric) x 2 colors (natural/red) represented 7 different actions (give/grasp/punch/press/write/pointing/none of these). Six participants were eliminated because they omitted more than the 50% of the responses.

Three repeated-measures ANOVAs on the Arcsine-transformed of the responses'occurence for each of our postures of interest (give/grasp/punch) were run with *Hand gender* (female vs. male) and *Type of action* (give/grasp/punch/press/write/pointing/none of these) as within-subjects factors. For sake of clarity we reported the actual percentage of the responses' occurrence.

Results on the hand mimicking the give posture

The main effect of the *Hand gender* factor was not significant, $F< .31$, while the main effect of the *Type of action* factor was significant, $F(6,132) = 47.16$, $MSe = .137$, $p<.001$, $\eta_p^2= .68$. Paired-samples t-tests showed that the hand that mimicked the give posture was identify as represented a give action (67%) more than the all other actions (5%, 0.3%, 0.5%, 0%, 8.4% and 19% for the grasp, punch, press, write, pointing, none of these postures respectively), $p_s< .001$. The interaction between *Hand gender* and *Type of action* factors was not significant, $F< 1.6$. The percentage of the responses' occurrence showed that, even not statistically significant, the hand that mimicked the give posture represented the giving action better if the hand was a female hand (70%) than a male one (65%).

Results on the hand mimicking the grasp posture

The main effect of the *Hand gender* factor was not significant, $F< .59$, while the main effect of the *Type of action* factor was significant, $F(6,132) = 25.83$, $MSe = .141$, $p<.001$, $\eta_p^2= .54$. Paired-samples t-tests showed that the hand that mimicked the grasp posture represented the grasp action (51%) more than the all other actions (1.9%, 0%, 11%, 9.5%, 2.4% and 24% for the give, punch, press, write, pointing, none of these postures respectively), $p_s< .05$. The interaction between *Hand gender* and *Type of action* factors was significant, $F(6,132) = 7.25$, $MSe = .022$, $p<.001$, $\eta_p^2= .25$. Paired-samples t-tests showed that the hand that mimicked the grasp posture represented a grasp action better if the hand was a female hand (58%) than a male one (44%), $p<.05$.

Results on the hand mimicking the punch posture

The main effect of *Hand gender* was not significant, $F< .05$, while *Type of action* factor was significant, $F(6,132) = 69.67$, $MSe = .105$, $p<.001$, $\eta_p^2= .76$. Paired-samples t-tests showed that the hand that mimicked the punch posture represented a punch action (75%) more than the all other actions (1.4%, 6.2%, 11%, 1.9%, 1.1% and 3% for the give, grasp, press, write, pointing, none of these postures respectively), $p_s< .001$. The interaction between *Hand gender* and *Type of action* factors was significant, $F(6,132) = 4.83$, $MSe = .020$, $p<.001$, $\eta_p^2= .18$. Paired-samples t-tests showed that the hand that mimicked the punch posture represented a punch action better if the hand was a male hand (80%) than a female one (71%), $p<.05$.

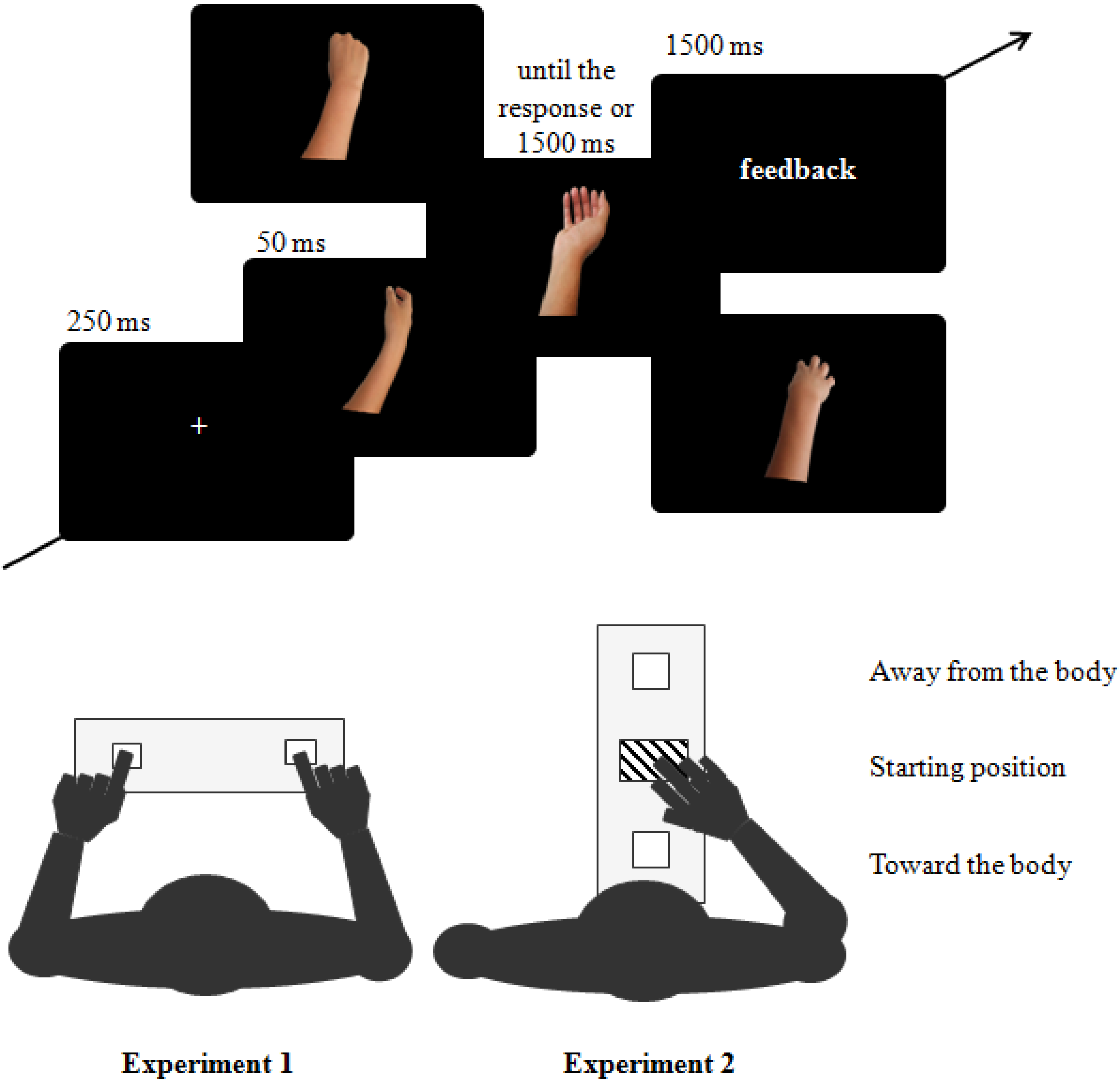
until the
response or
1500 ms
1500 ms
feedback
50 ms
250 ms
+
Away from the body
Starting position
Toward the body
Experiment 1
Experiment 2

Figure 1

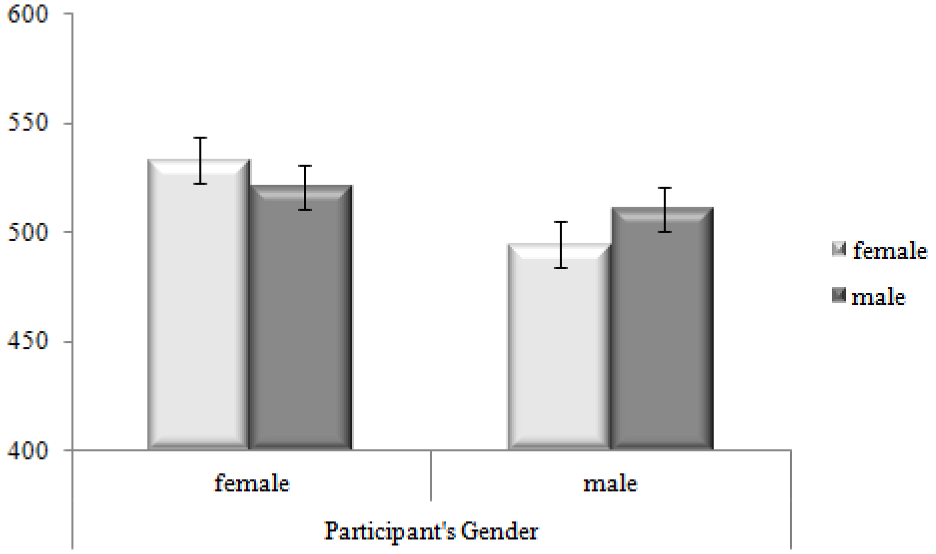

Figure 2

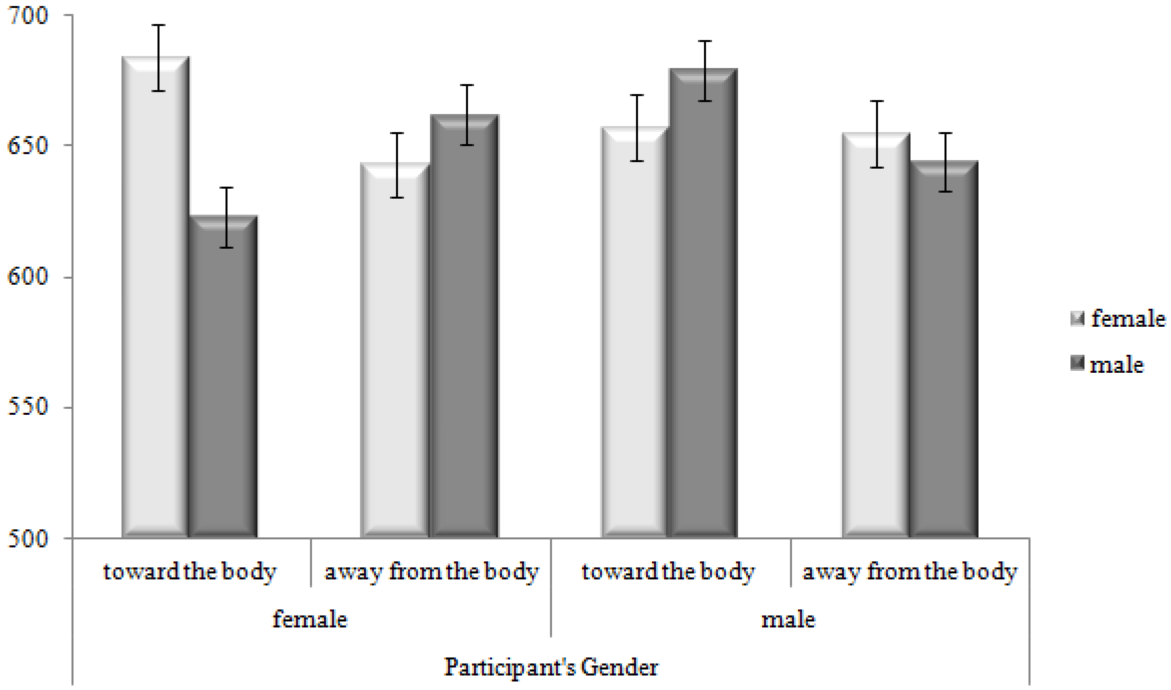

Figure 3

Table 1

Hand gender	Color	Mean	Std.Error
female	Natural	503	14.3
	Red	525	16.5
male	Natural	515	14.8
	Red	517	14.0

Hand gender	Posture	Mean	Std.Error
female	give	510	14.9
	grasp	506	14.2
	punch	526	17.4
male	give	543	17.5
	grasp	511	14.3
	punch	493	12.5

Hand gender	Participant's gender	Mean	Std.Error
female	female	533	21.4
	male	521	20.3
male	female	495	21.4
	male	511	20.3

Table 2

Hand gender	Posture	Mean	Std.Error
female	Give	657	16.8
	Grasp	660	15.6
	Punch	663	16.5
male	Give	668	18.6
	Grasp	649	17.8
	Punch	639	16.9

Participant's gender	Hand gender	Color	Mean	Std.Error
female	female	natural	659	22.5
		red	668	23.2
	male	natural	642	23.9
		red	642	25.6
male	female	natural	658	22.5
		red	654	23.2
	male	natural	652	23.9
		red	671	25.6

Participant's gender	Hand gender	Movement	Mean	Std.Error
female	female	Toward the body	684	25.2
		Away from the body	643	22.6
	male	Toward the body	623	25.6
		Away from the body	662	26.1
male	female	Toward the body	657	25.2
		Away from the body	655	22.6
	male	Toward the body	679	25.6
		Away from the body	644	26.1

Figure and Table Captions

Fig. 1 Example of a sequence of events in a trial (top panel). Example of the response set for both Experiment 1 and 2 (bottom panel). Note that elements are not drawn to scale

Fig. 2 Mean RTs in ms as a function of *Participant's gender* (female vs. male), *Hand gender* (female vs. male) interaction for Experiment 1. Bars represent standard errors of the mean

Fig. 3 Mean RTs in ms as a function of *Participant's gender* (female vs. male), *Hand gender* (female vs. male) and *Movement* (toward the body *vs.* away from the body) interaction for Experiment 2. Bars represent standard errors of the mean

Table 1 Mean RTs and Standard Error (in ms) for Experiment 1 as a function of *Hand gender* (female vs. male) and *Color* (natural vs. red) interaction (top panel), of *Hand gender* (female vs. male) and *Posture* (give vs. grasp vs. punch) interaction (middle panel), and of *Hand gender* (female vs. male) and *Participant's gender* (female vs. male) interaction (bottom panel)

Table 2 Mean RTs and Standard Error (in ms) for Experiment 2 as a function of *Hand gender* (female vs. male) and *Posture* (give vs. grasp vs. punch) interaction (top panel), of *Participant's gender* (female vs. male), *Hand gender* (female vs. male) and *Color* (natural vs. red) interaction (middle panel), and of *Participant's gender* (female vs. male), *Hand gender* (female vs. male) and *Movement* (toward the body *vs.* away from the body) interaction (bottom panel)