Fooling the Kickers but not the Goalkeepers: Behavioral and Neurophysiological Correlates of Fake Action Detection in Soccer

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Introduction
Optimal interactions with complex, dynamic environments require the ability to build up anticipatory responses to the motion of objects or creatures. This predictive ability allows an individual to compensate for the intrinsic delay between fast stimulus dynamics and the time required to accurately perceive and plan an appropriate motor response. An individual’s perceptual experience with moving objects establishes internal models of the rules that govern their motion in the environment and creates anticipatory representations of the motion sequence (Hubbard 2005; Zago and Lacquaniti 2005; Motes et al. 2008). However, several studies have shown that the anticipatory representations of others’ behaviors require the internal predictive models of actions established during direct, not merely perceptual, motor experience (Verfaillie and Daems 2002; Flach et al. 2004; Ramnani and Mirall 2004). Thus, an individual’s ability to create an anticipatory representation of an action course is dependent upon motor expertise, and it is maximal for movements that belong to the observers’ motor repertoire.

In keeping with the notion of shared representations of perceived and executed actions (Prinz 1997; Hommel et al. 2001), behavioral studies have shown that mere motor experience of a given action may improve the visual discrimination of full (Hecht et al. 2001) as well as point-light (Casile and Giese 2006) displays of the same action even if no visual feedback is provided during the execution phase. In a similar vein, neuroimaging studies have provided evidence that the activity of the fronto-parietal system in coupling the representations of executed and observed actions (Rizzolatti and Craighero 2004; Van Overwalle and Baetens 2009) is modulated by the observers’ motor experience (Calvo-Merino et al. 2005, 2006; Reithler et al. 2007; Orgs et al. 2008). Moreover, learning to execute complex dance patterns modulates neural motor activity during the observation of practiced, when compared with visually familiar but unpracticed movements (Cross et al. 2006; Cross, Hamilton et al. 2009; Cross, Kraemer et al. 2009).

The ability to create anticipatory representations of ongoing actions is crucial in sports as it involves movements performed at high speed. Thus, athletes are often required to make predictions based on the initial action cues the opponents provide, because waiting to perceive the full consequences of their moves would result in a highly ineffective strategy. Behavioral investigations have shown, indeed, that elite athletes present superior abilities not only in performing actions, but also in predicting and anticipating the other players’ actions (Farrow and Abernethy 2003; Abernethy and Zawi 2007; Abernethy et al. 2008; Weissenstein et al. 2008). Using a temporal occlusion paradigm, in which the presentation of sport actions is interrupted at different delays from onset, research in a variety of different sport domains demonstrated that motor experts are faster and more accurate than novices in predicting the outcome of observed actions. Importantly, while both expert athletes and observers (e.g. coaches or supporters) are more accurate than novices in predicting the fate of sport actions by viewing the initial ball trajectory, only athletes, but not expert observers, base their predictions on action body kinematics (Aglioti et al. 2008; Urgesi et al. 2012) and visual body representations (Abreu et al. 2012). Crucially, when compared with naive and expert observers, the superior predictive abilities of elite basketball players are associated with differential activation of the motor cortex during their observation of erroneous versus correct shots (Aglioti et al. 2008). Thus, achieving excellence in sports...
might also be related to the fine tuning of specific anticipatory motor simulation mechanisms that allow for an earlier and more accurate prediction of another’s future actions.

While many studies have documented that the motor simulation of others’ body kinematics is associated with the superior perceptual abilities of motor experts, little attention has been paid to the relative role of motor and visual expertise on the ability to anticipate fooling behaviors (Calvino-Merino et al. 2010; Urgesi et al. 2012). This absence is surprising because in sports, as in any competitive social setting, players aim to fool others; they attempt to decrease the information available or to provide misleading information that makes the observers more error prone (Jackson et al. 2006).

Studies on rugby (Jackson et al. 2006; Brault et al. 2012), basketball (Sebanz and Shiffrar 2009), and handball (Cañal-Bruland and Schmidt 2009; Cañal-Bruland et al. 2010) have shown that expert players are better than novices in recognizing when other players are attempting to fool them. Indeed, fooling players may be able only to approximate the general kinematics of an action but not its full characteristics (Brault et al. 2010, 2012). Because kinematics offer relevant information about a player’s deceptive intentions (Runeson and Frykholm 1983; Sartori et al. 2011), experts have acquired the capability to detect the exaggerations of the body kinematics that arise from intended deceptions (Brault et al. 2012). In certain situations, however, such as reacting to a boxing opponent’s stroke (Ripoll et al. 1995) or a goalkeeper’s attempt to intercept a penalty kick for a goalkeeper (Dessing and Craig 2010), it is crucial that the athlete relies on visual processing of the last action phases (e.g. consequences on the object motion) rather than on the possibly fooling body kinematics of the opponent player. Thus, the greater action simulation abilities of motor experts may become detrimental because it induces a greater susceptibility to effective fooling body action. In keeping with this suggestion, a greater susceptibility to opponents’ body fooling movements has been found among expert French boxers, who presented more false alarms in responding to fake actions than intermediate and novice players (Ripoll et al. 1995). Thus, the use of pure visual processing strategies versus visual–motor expertise may be crucial in optimizing predictions of fooling body actions. While athletes seem to outperform novices in detecting fooling behaviors, it is unclear whether this ability relies on motor or visual expertise (Jackson et al. 2006; Cañal-Bruland and Schmidt 2009; Sebanz and Shiffrar 2009; Cañal-Bruland et al. 2010).

To explore the role of motor and visual expertise in anticipating fooling actions, we investigated the ability of expert kickers, goalkeepers, and novices to observe a series of videotaped penalty kicks performed by a kicker model and to predict their fate to the left or to the right of the goal. Each taped penalty kicks performed by a kicker model and to kickers, goalkeepers, and novices to observe a series of video-participating fooling actions, we investigated the ability of expert kickers, goalkeepers, and novices to observe a series of videotaped penalty kicks performed by a kicker model and to predict their fate to the left or to the right of the goal. Each taped penalty kicks performed by a kicker model and to predict their fate to the left or to the right of the goal. Each taped penalty kicks performed by a kicker model and to predict their fate to the left or to the right of the goal.

The kickers trained for a mean of 7.8 h per week (SD = 3.3) and had played soccer for 14.5 years (SD = 4.5). Goalkeepers trained for a mean of 6.2 h per week (SD = 1.6) and had played soccer for 16 years (SD = 6). No difference was observed between the weekly training hours (P = 0.092) and years of experiences (P = 0.423) of kickers and goalkeepers. All kickers and goalkeepers played in Amateur Soccer League teams. Six out of the 16 kickers were forward players, 7 were midfielder players, and 3 were defender players. However, all of them had experience and regularly practiced in shooting penalty kicks. One forward kicker and one goalkeeper were second substitutes in their actual team, while the remaining participants were first-line players.

Materials and Methods

Participants

Experiment 1

Sixteen expert soccer kickers aged 18–30 years (mean = 22 years, standard deviation [SD] = 3), 16 goalkeepers aged 19–36 years (mean = 24 years, SD = 5.3), and 16 novices (no experience playing soccer) aged 20–28 years (mean = 23 years, SD = 2.2) took part in Experiment 1. All the participants were men. Two kickers, 3 goalkeepers, and 1 novice were left-handed, while the remaining participants were right-handed (Briggs and Nebes 1975). All participants but one reported right-foot dominance; one of the novices was right-handed but exhibited left-foot dominance. Kickers trained for a mean of 7.8 h per week (SD = 3.3) and had played soccer for 14.5 years (SD = 4.5). Goalkeepers trained for a mean of 6.2 h per week (SD = 1.6) and had played soccer for 16 years (SD = 6). No difference was observed between the weekly training hours (P = 0.092) and years of experiences (P = 0.423) of kickers and goalkeepers. All kickers and goalkeepers played in Amateur Soccer League teams. Six out of the 16 kickers were forward players, 7 were midfielder players, and 3 were defender players. However, all of them had experience and regularly practiced in shooting penalty kicks. One forward kicker and one goalkeeper were second substitutes in their actual team, while the remaining participants were first-line players.

Experiment 2

Ten soccer kickers aged 19–30 years (mean = 23.1 years, SD = 3.3), 10 goalkeepers aged 19–36 years (mean = 23.2, SD = 5.4), and 10 novices (no experience playing soccer) aged 20–28 years (mean = 23.2 years, SD = 2.5) took part in Experiment 2. All participants were men, and all were right-handed (Briggs and Nebes 1975), except one kicker, one goalkeeper, and one novice who were left-handed. One novice and one goalkeeper were right-handed with left-foot dominance. The other participants reported right-foot dominance. Kickers trained for a mean of 7.7 h per week (SD = 3.1) and had played soccer for 15.9 years (SD = 4.9). Goalkeepers trained for a mean of 6.6 h per week (SD = 2.3) and had played soccer for 15.4 years (SD = 6.4). No difference was observed between the weekly training hours (P = 0.579) and years of experiences (P = 0.847) of kickers and goalkeepers. All kickers and goalkeepers played in Amateur Soccer League teams. Three out of the 10 kickers were forward players, 5 were midfielder players, and 2 were defender player. All of them had experience and regularly practiced in shooting penalty kicks. All kickers and all but one goalkeepers were first-line players in their team.

Different groups of participants were tested in the behavioral (Experiment 1) and in the TMS studies (Experiment 2). The kickers...
and goalkeepers tested in both experiments played in different Amateur Leagues with respect to the model player, thus ruling out any confounding effect of familiarity. We considered our kickers and goalkeepers as experts in soccer on the basis of years of experience and weekly hours and type of practice, which not only included match playing but also specific soccer training. Furthermore, all the players were officially engaged in Amateurs League teams belonging to the “Campionato Dillettanti”, which comprises the entry tiers of the Italian Football System organized by national or regional committees, and received a small refund (€50–500) for their sport activity (i.e. they were not recreational players). We included both right- and left-handed individuals in the 2 experiments with the expectation that handedness should not exert strong and reliable effects on action perception abilities and motor activation during observation of wholebody movements. Indeed, although motor activation may be modulated by the laterality of the observed body part and by the handedness of the observer, largely bilateral fronto-parietal activations have been reported in both right- and left-handed individuals (Aziz-Zadeh et al. 2002, 2006; Vingerhoets et al. 2012). The participants gave their written informed consent and received information about the experimental hypothesis only after the experimental tests were completed. The procedures, approved by the ethics committee of the Scientific Institute “E. Medea”, were in accordance with the ethical standards of the 1964 Declaration of Helsinki. None of the participants had neurological, psychiatric, or other medical problems or any contraindication to TMS. There were no reports or observations of any discomfort or adverse effects during TMS.

Stimuli and Apparatus
Stimuli were created from digitally recorded videos of a male expert soccer kicker (playing in an Amateur Soccer League team) while he performed a series of penalty kicks directed to the left or to the right side of the goal. The kicker was instructed to place the ball at about 2.5–3.5 m to the left or to the right of the goal center. The videos were taken from the front plane, at a distance of 11 m from the penalty mark, where the ball was initially positioned; thus, the camera was placed at an 8 of 150 cm from the center of the goal line, corresponding to the goalkeeper’s starting position. We selected 8 videos, 4 exhibiting left-directed kicks, and 4 exhibiting right-directed kicks. From each selected video, we extracted a 1650 ms sequence around the point of the foot-ball contact, thus including the initial kicker’s run-up and the visible ball trajectory until the high level of the beginning of the goal area. With this procedure, we ensured that the foot-ball contact occurred at 1200 ms after each video onset, although the starting position of the model kicker and the visible ball trajectory could slightly vary for the different videos (less than ±100 ms). Each 1650 ms video sequence was split into 2 video-clips by using the Adobe Premiere software (Adobe Systems Incorporated, San Jose, CA, USA). The first video-clip duration was 1167 ms and included the action up to the instant at which the foot touches the ball (from now on called the body-kinematics video-clip). The second video-clip duration was 483 ms and covered the period from the foot-ball contact frame to the disappearance of the ball behind the field of view set at the beginning of the goal area (from now on called the ball-trajectory video-clip). The ball motion had a velocity of approximately 11–12 m/s during the visible trajectory. Each body-kinematics video-clip was either combined with its own ball-trajectory video-clip (congruent video-clips) or with the ball-trajectory video-clip of a kick in the opposite directions (incongruent video-clips). This way, we obtained 8 congruent (4 left- and 4 right-directed) and 8 incongruent action video-clips (4 with left-directed body kinematics and right-directed ball trajectory, and 4 with right-directed body kinematics and left-directed ball trajectory; see Fig. 1 and Supplementary Videos 1–4).

During the experiment, participants sat in a dimly light room at 80 cm away from a 15 in. LCD monitor (resolution, 1024 × 768 pixels; refresh frequency, 60 Hz), on which video-clips were presented on a black background and subtended a 14.4° × 11.5° region. Stimulus presentation timing, electromyographic (EMG) recording, and TMS triggering, as well as the randomization of stimuli in block, were controlled by E-prime V1.2 software (Psychology Software Tools Inc., Pittsburgh, PA, USA). The rate of movie presentation was set at a 30 Hz (33 ms per snapshot).

Procedure
Experiment 1
A temporal occlusion paradigm (Abernethy and Zawi 2007; Aglioti et al. 2008) was used for the behavioral study, in which the presentation of each video-clip was interrupted at 3 different instants from the onset, namely: 1) 1133 ms, showing the player’s initial body movements; 2) 1200 ms, soon after the foot-ball contact; and 3) 1267 ms, showing also the initial ball trajectory. Thus, a total of 48 video-clips were presented. It is worth noting that the first incongruent cue was the foot-ball contact presented at 1167 ms from video-clip onset. In the 1133 ms trials, no incongruent cues were present and the same video-clips were shown in the congruent and incongruent trials; in the 1200 ms trials, incongruent foot-ball contacts along with the initial ball motions were shown; and in the 1267 ms trials, the incongruent trajectory of the ball was also visible.

Each participant was tested in a single experimental session lasting approximately 45 min. Four blocks made by 48 trials were administered to each participant for a total of 192 trials (32 trials for each action type × duration cell). Resting was allowed between blocks.

A trial started with the presentation of a central 1° × 1° fixation cross lasting for 500 ms, which was followed by the experimental video-clips presentation at the center of the monitor. At the end of each video-clip presentation, a prompt frame was presented requesting the participants to press, respectively, with the left or the right index finger the left or the right button of the computer mouse to indicate whether the kick was directed to the left or to the right. Participants were instructed to be as accurate and fast as possible. Response accuracy and the time taken to respond measured from the onset of the prompt frame (latency) were recorded and analyzed.

Experiment 2
The trial structure for the TMS experiment resembled the one applied in Experiment 1, but in this case, both congruent and incongruent video-clips were presented without interruption. Importantly, the TMS pulse was released at 1235 ms after the video-clip onset, that is, just after the instant of foot-ball contact, and at 1300 ms after video-clip onset, that is, at the initial ball-trajectory phase. Participants were tested in a single experimental session lasting approximately 90 min. Four blocks made of 32 trials were administered to each participant for a total of 128 video-clip presentation trials (16 trials for each action type × TMS delay cell). Presentations of congruent and incongruent videos and the 3 different TMS delays were randomized within each block. Furthermore, at the beginning and the end of the video presentation session, 2 blocks made of 16 trials were administered as the baseline in which the TMS pulses were delivered while participants fixated on a white-colored cross on a black background. A similar timing for stimulus duration and for TMS delay was applied for both the video observation and baseline sessions. An inter-pulse interval of at least 10 s was always present between trials. Participants were instructed to keep their right hand on a pillow and to relax their muscles fully. They were asked to pay attention to the stimuli and to try to determine as quickly as possible whether the kick was left- or right-directed. No overt responses were requested to avoid muscular contractions that could affect cortico-spinal excitability. In case a muscular contraction was detected, the trial presentation was suspended and the participants invited once again to find their full muscular relaxation.

At the end of the TMS session, the same procedure used in Experiment 1 was administered to all participants. The decision to administer the behavioral task in Experiment 2 only after the TMS session ensured that participants kept their maximal attention to the stimuli during motor-evoked potential (MEP) recording. It should be noted, however, that presenting the behavioral task after participants were exposed to the same in the TMS session may have altered their
prediction performance when compared with the conditions of Experiment 1.

**Electromyography Recording and TMS**
We recorded MEPs simultaneously from the right medial gastrocnemius (GAM), tibialis anterior (TA), and extensor carpi ulnaris (ECU) muscles. We recorded from a gravitational (GAM) and an antigravitational muscle (TA) of the right lower limb and from an extensor forearm muscle to check for the muscle specificity of any modulation related to the different observational conditions. Leg and arm muscle activity was recorded within the same experimental block to avoid participants’ reduction in attention and/or learning effects.

Surface Ag/AgCl cup electrodes (1 cm diameter) were placed in a belly-tendon montage for each muscle and connected to a Viking IV electromyography equipment (Nicolet Biomedical) for amplification, band-pass filtering (20 Hz–3 kHz), and digitization of the EMG signal. The ground electrode was placed over the knee for the GAM and the TA, and over the dorsal part of the elbow for the ECU muscle recordings. The sampling rate of the EMG signal was 20 kHz. To make sure that there was no unwanted background EMG activity before the magnetic pulse, we had the signal of each muscle displayed additionally in separate channels set at high sensitivity (50 µV). Moreover, during the preliminary session, we sent EMG signals to loudspeakers to provide participants with an auditory feedback of their muscle relaxation. A pre-stimulus recording of 80 ms was used to check for the presence of EMG activity before the TMS pulse. Trials presenting an EMG amplitude, before the TMS pulse, >50 µV were discarded from the analysis (<2%).

Single-pulse TMS was performed by means of a 110-mm double-cone stimulation coil (standard Magstim plastic-covered coil), connected to a Magstim Rapid (The Magstim Company, Carmarthenshire, Wales), producing a maximum output of 2 T at the coil surface (pulse duration, 250 µs; rise time, 60 µs). During the recording session, the coil position was centered approximately over the vertex in correspondence with the optimal scalp position (OSP), defined as the position from which MEPs with maximal amplitude were recorded. The OSP was detected by moving the intersection of the coil in 1-cm steps around the lower limb area of the left motor cortex and by delivering TMS pulses at constant intensity. TMS was administered using posterior–anterior currents in the brain. Participants wore a tightly fitting bathing cap on which the scalp position for simulation was marked. The coil was held on the scalp by a coil holder with an articulated arm and the experimenter continuously checked the position of the coil with respect to the marks to easily compensate for small movements of the participant’s head during data collection. We determined the resting motor threshold (rMT), defined as the lowest stimulus intensity able to evoke 5 out of 10 MEPs with an amplitude of at least 50 µV. The OSP and the rMT were determined for the higher threshold muscle, namely the GAM, to avoid the loss of any differential modulations involving the less excitable muscle. Stimulation intensity during the recording session was 120% of the rMT. Importantly, the chosen scalp position and stimulation intensity allowed to record a clear and stable EMG signal (10 MEPs out of 10 TMS pulses) from all recorded leg and arm muscles in all participants (Krings et al. 1998). There was no observable difference ($F_{2,28} < 1$) of rMT among kickers (mean = 52.8%, SD = 8.6%), goalkeepers (mean = 55.91%, SD = 8.2%), and novices (mean = 53.4%, SD = 7.81%). MEPs peak-to-peak amplitude (in millivolts) was collected and stored on a computer for offline analysis.

**Data Analysis**
For the behavioral experiments, we calculated the percentage of correct responses (accuracy) provided by each participant in each experimental condition. For the incongruent video-clips, correctness of responses was defined on the basis of the direction indicated by the last available cue, which was provided by body movements for the 1133 ms video-clips and by the ball trajectory for the 1200 and 1267 ms video-clips. Trials in which participants responded earlier than 100 ms and later than 3000 ms from the prompt screen onset were discarded from the analysis. Discarded trials amounted to 3.4% (SD = 3.93) of the total trials in Experiment 1 and 2.4% (SD = 2.73) in Experiment 2. No difference between the 3 groups ($F_{2,45} < 1$) was
found. Because the incorrect responses for the incongruent video-clips were based on accurate perception of the body movements, we considered the latencies for both correct and incorrect responses to rule out that the response latency was biased just for trials in which participants responded on the basis of the ball trajectory. It is worth noting, however, that the latency of responses prompted at the offset of video-clip presentation cannot be considered as a reliable measure of the participant’s perceptual abilities. Rather, latency reflects differences in response strategies which may affect performance accuracy. Individual accuracy and latency values were entered in a 3-way mixed-model analysis of variance (ANOVA) that included group (kickers, goalkeepers, novices) as a between-subject variable, and video-clip duration (1133, 1200, 1267 ms) and action type (congruent, incongruent) as within-subject effects.

For the TMS experiment, the raw MEP amplitude of each trial and for each participant was normalized (T-scores) on the total MEPs recorded from each muscle. The individual mean T-score values of the MEPs collected from each muscle at 1233 and 1300 ms after the onset of congruent and incongruent video-clips were expressed as differences from the mean T-score value of MEPs collected during the baseline condition at the corresponding TMS delay (1233 and 1300 ms). This difference provided an index of MEP amplitude change measured in T-score units. The individual MEP amplitude change indexes were entered into a 4-way mixed-model ANOVA that included group (kickers, goalkeepers, novices) as a between-subject variable and muscle (GAM, TA, ECU), TMS delay (1233, 1300 ms), and action type (congruent, incongruent) as within-subject effects. Furthermore, 3 separate follow-up 3-way mixed-model ANOVAs (group x TMS delay x action type), one for each muscle, were conducted to explore the source of the significant 4-way interaction. All pair-wise comparisons were performed using the Duncan post hoc test. Furthermore, the Pearson correlation coefficients were computed in Experiment 2 between the accuracy of the 3 groups for the incongruent actions at the 1200 and 1267 ms video-clip durations and the normalized amplitude of MEPs recorded from the 3 muscles at the 1233 and 1300 ms TMS delays, respectively. A Bonferroni correction procedure was used to control P-values for multiple correlations testing for each group (6 correlations). A significance threshold of P < 0.05 was set for all statistical analyses. Data are reported as mean ± standard error of the mean (SEM).

Results

**Experiment 1: Behavioral Study**

The ANOVA on accuracy revealed a non-significant main effect of group (F\textsubscript{2,45} = 2.14, P = 0.129), but significant effects of video-clip duration (F\textsubscript{2,90} = 133.87, P < 0.001), action type (F\textsubscript{1,45} = 311.25, P < 0.001), and of their interaction (F\textsubscript{2,90} = 207.95, P < 0.001). Crucially, however, the effects of action type and video-clip duration were qualified by significant 2-way interactions between video-clip duration and group (F\textsubscript{1,90} = 6.39, P < 0.001), between action type and group (F\textsubscript{2,45} = 6.47, P = 0.003), as well as by a significant 3-way interaction (F\textsubscript{4,90} = 3.03, P = 0.021). This pattern of results suggests that the effects of video-clip duration and congruence were different in the 3 groups (Fig. 2). Post hoc tests showed that performance for congruent and incongruent actions did not differ in any group at 1133 ms (all P > 0.51), whereas all groups were impaired by the appearance of the incongruence between body movements and ball trajectory at 1200 and 1267 ms video-clip durations (all P < 0.007). Thus, incongruence impaired the performance of the participants even when the ball trajectory clearly indicated the (incongruent) direction of the penalty kick.

When the performance of the 3 groups for the congruent actions was considered separately, we found that kickers and goalkeepers did not improve their performance with longer video-clip durations (all P > 0.2). In contrast, novices were better at 1267 ms than at 1133 ms (P = 0.001). Thus, while kickers and goalkeepers were able to judge the direction of the penalty kick by viewing only the movements of the model’s body and had no further advantage from viewing the ball trajectory, the novices’ performance improved by viewing the ball trajectory. Furthermore, for the congruent actions, kickers and goalkeepers were better than novices at 1133 ms (P = 0.041 and 0.043, respectively) but not at longer video-clip durations (all P > 0.3). No difference was observed between kickers and goalkeepers at any video-clip duration (all P > 0.9).

A different pattern of results was revealed for the incongruent actions. All groups presented a remarkable drop of performance from the 1133 ms to the 1200 ms video-clip duration (all P < 0.001), when the foot-ball contact was incongruent with respect to the body kinematics, while all groups improved at the 1267 ms video-clip (all P < 0.001), when the incongruent ball trajectory was clearly present. However, while novices had a comparable performance at 1133 ms and 1267 ms (P = 0.224), kickers (P < 0.001) and goalkeepers (P = 0.002) were better at 1267 ms than at 1133 ms. This finding suggests that compared with novices, kickers and goalkeepers seemed to present a greater inertia for changing their decision when they observed the incongruent ball trajectory, because it conflicted with the strong internal representation of the observed action created by their reading of body kinematics. It is important to note that whereas goalkeepers were then able to update their decisions on the basis of the incongruent ball trajectory, kickers did not. This result was confirmed by the direct comparisons among the 3 groups’ performances for the incongruent actions. At the 1133 ms video-clip duration, novices were less accurate than kickers (P = 0.036) and goalkeepers (P = 0.018), who, in turn, showed a comparable performance (P = 0.754). In contrast, at the 1200 and 1267 ms video-clip durations, kickers were less accurate than novices (P = 0.002 and <0.001, respectively) and goalkeepers (P = 0.059 and <0.001), who, in turn, had a comparable performance (all P > 0.15). Although the performance of all groups improved in the longer video-clip duration, the pattern of between-group difference did not change from the 1200 to the 1267 ms video-clip duration. This shows that the interaction between group, action type, and video-clip duration was due to the change of performance from the 1167 to the 1200 ms video-clip duration, where the incongruent foot-ball contact and initial ball-trajectory cues were presented. In summary, we found that both kickers and goalkeepers were better than novices in predicting the fate of congruent actions due to their superior ability to read the model’s body kinematics. Crucially, goalkeepers presented a greater resistance to the fooling body actions when compared with kickers who were even more fooled than novices by the incongruence between body movements and ball trajectory.

Response latencies were analyzed to test whether the greater susceptibility to incongruent actions of kickers was due to their decision to answer before completing the perceptual analysis of the ball trajectory. If so, we would expect comparable latencies for the kickers’ responses to congruent and incongruent actions and faster responses for kickers when compared with novices and goalkeepers. The ANOVA on latencies revealed a non-significant main effect of group
(F_{2,45} = 1.77, P = 0.182), suggesting that the overall response speed did not differ among the groups. Significant main effects of video-clip duration (F_{2,90} = 66.54, P < 0.001) and action type (F_{1,45} = 19.74, P < 0.001) revealed shorter latencies with longer video-clip durations (all P’s < 0.001) and for congruent when compared with incongruent actions. A significant interaction between video-clip duration and action type (F_{2,90} = 9.78, P < 0.001) showed that the difference between congruent and incongruent actions was significant at 1200 ms (P = 0.001) and at 1267 ms (P < 0.001), but not at 1133 ms (P = 0.445). Furthermore, significant 2-way interactions between group and video-clip duration (F_{1,90} = 2.86, P = 0.028) and between group and action type (F_{2,45} = 4.38, P = 0.018) revealed an across-group modulation of the effects of video-clip duration and action type. Indeed, while latencies were shorter with longer video-clip durations for novices (all P’s < 0.001) and goalkeepers (all P’s < 0.02), the kickers’ responses become faster at 1200 and 1267 ms when compared with 1133 ms (P = 0.014 and < 0.001, respectively), but no difference was observed between 1200 and 1267 ms (P = 0.17). Furthermore, while no difference was observed between goalkeepers and novices at any video-clip duration (all P’s > 0.4), the kickers’ latency was comparable to that of goalkeepers and novices at 1133 ms (P = 0.421 and 0.985, respectively) and at 1200 ms (P = 0.099 and 0.293), but was longer at 1267 ms (P = 0.034 and 0.036). For congruent actions, kickers were comparably fast to the goalkeepers (P = 0.228) and to the novices (P = 0.546), but for incongruent actions, they were slower compared with goalkeepers (P = 0.049) but not to novices (P = 0.094). No difference was observed between goalkeepers and novices for congruent (P = 0.498) and incongruent actions (P = 0.689). Importantly, while kickers were slower for incongruent than for congruent actions (P < 0.001), the difference was only marginally significant for goalkeepers (P = 0.062) and non-significant for novices (P = 0.387). Thus, the analysis of latencies suggested

![Figure 2: Results of the behavioral task administered in Experiment 1. Mean (±SEM) accuracy (upper graphs) and latency of responses (lower graphs) are showed according to the action type (congruent actions in the left graphs, incongruent actions in the right graphs), video-clip duration (1133, 1200, and 1267 ms), and observer group (kickers, goalkeepers, and novices). Note that no incongruent cue was shown in the 1133 ms video-clip duration, where performance is comparable for congruent and incongruent actions. Asterisks indicate the significant pair-wise comparisons (P < 0.05) between the performance of the 3 groups in each action type × video-clip duration condition. Kickers and goalkeepers were more accurate than novices in predicting the direction of the observed kick on the basis of the initial ball trajectory (1133 ms), while no between-group difference was found for actual actions at 1200 and 1267 ms. Importantly, kickers performed less well than goalkeepers in detecting incongruent body kinematics and ball trajectory at 1200 and 1267 ms video-clips. No specific modulation according to the congruence between body kinematics and ball trajectory was obtained for latencies. Interestingly, kickers were slower than goalkeepers and novices at the longest video-clip duration.](image-url)
that overall the kickers’ responses were not faster than that of
goalkeepers and novices and that they even slowed down in
incongruent conditions. This result rules out the hypothesis
that kickers simply did not consider the information provided
by the ball trajectory to supply their perceptual judgments.
Furthermore, the non-significant 3-way interaction
\((F_{4,34} = 1.39, \, P = 0.243)\) ruled out that any speed-accuracy
trade-off explained the results on accuracy.

**Experiment 2: TMS Study**

**MEPs Data**

Table 1 shows the raw amplitude values for MEPs recorded
from the GAM, TA, and ECU muscles of kickers, goalkeepers,
and novices in the 2 baselines and in the 4 (2 TMS delays × 2
action type) experimental conditions. The ANOVA on the
MEP amplitude change indexes (Fig. 3) revealed a non-
significant main effect of group \((F_{2,27} = 2.13, \, P = 0.138)\) but a
significant interaction between group and action type
\((F_{2,27} = 3.69, \, P = 0.038)\). Post hoc tests showed that incongruent
when compared with congruent actions engendered a
lower motor facilitation in goalkeepers \((6.21 \pm 5.16, \, P = 0.006)\) but not in kickers \((2 \pm 1.84, \, P = 0.656)\) or novices
\((4.68 \pm 4.97, \, P = 0.424)\). No other pair-wise comparison resulted in a significant difference \((all \, P > 0.05)\). Furthermore, no other main effect, or 2- or 3-way interaction resulted significant \((all \, P < 0.32)\). Crucially, however, a significant 4-way interaction between group, muscle, TMS delay, and action type was found \((F_{1,54} = 2.55, \, P = 0.049)\). To explore the source of this interaction, we ran 3 separate 3-way ANOVAs, one for each muscle, testing separately the interaction between group, TMS delay, and action type on MEPs recorded from lower and upper limb muscles.

The ANOVA on the GAM MEPs revealed a significant 3-way interaction \((F_{2,27} = 6.58, \, P = 0.005)\), while no main effect or 2-way interaction resulted significant \((all \, F < 2.52, \, P > 0.12)\). Post hoc tests showed that the facilitation of the kickers’ GAM MEPs was not modulated by the incongruence at the TMS delay of 1233 ms \((3.56 \pm 2.1 \, vs. \, 3.04 \pm 1.91, \, P = 0.504)\) and 1500 ms \((2.94 \pm 1.95 \, vs. \, 2.37 \pm 2.17, \, P = 0.326)\). In contrast, the goalkeepers’ motor facilitation was reduced by the incongruence at the earlier \((6.81 \pm 1.89 \, vs. \, 4.84 \pm 1.91, \, P = 0.002)\) but not at the later TMS delay \((6.51 \pm 1.87 \, vs. \, 5.73 \pm 1.92, \, P = 0.161)\). On the other hand, the novices’ motor facilitation was increased by the incongruence at the earlier \((2.81 \pm 1.61 \, vs. \, 4.35 \pm 1.32, \, P = 0.016)\) but not at the later TMS delay \((5.05 \pm 2.09 \, vs. \, 3.97 \pm 1.78, \, P = 0.074)\). Furthermore, the novices’ MEPs were more facilitated at 1300 ms than at 1233 ms for congruent \((P < 0.001)\), but not for incongruent actions \((P = 0.476)\). No other with-in group or between-group pair-wise comparison produced significant results.

A similar pattern of results was obtained from the ANOVA
on TA MEPs: A significant 3-way interaction between group,
TMS delay, and action type \((F_{2,27} = 4.11, \, P = 0.028)\) and non-
significant main effects or 2-way interactions \((all \, F < 3.1, \, P > 0.06)\). Post hoc tests showed that for kickers, the facilitation of TA MEPs was not modulated by incongruence at both TMS delays \((1233 \, ms: \, 0.72 \pm 2.1 \, vs. \, 1.06 \pm 2.07, \, P = 0.599; \, 1300 \, ms: \, 0.93 \pm 2.04 \, vs. \, 0.83 \pm 1.91, \, P = 0.857)\). In contrast, for goalkeepers, motor facilitation of TA MEPs was lower for incongruent than for congruent actions at 1233 ms \((2.73 \pm 2.41 \, vs. \, 4.35 \pm 2.6; \, P = 0.016)\), but not at 1300 ms \((5.34 \pm 2.28 \, vs. \, 4.78 \pm 2.09, \, P = 0.339)\). Furthermore, the goalkeepers’ facilitation for incongruent actions was lower at 1333 ms than at 1500 ms \((P = 0.003)\). For novices, motor facilitation was higher for incongruent \((4.15 \pm 1.61)\) than for congruent \((2.42 \pm 1.63)\) actions at the earlier TMS delay \((P = 0.01)\), while no difference was found at the later TMS delay \((3.58 \pm 2.18 \, vs. \, 3.09 \pm 1.82, \, P = 0.398)\). No other pair-wise comparison resulted in a significant difference. In summary, the 3 groups showed a different incongruence-related modulation of the MEPs recorded from the 2 lower limb muscles when the TMS pulse followed the presentation of the foot-ball contact: No modulation for kickers, a reduction for goalkeepers, and an increase in motor facilitation for novices.

The ANOVA on the MEPs recorded from the ECU revealed a
significant main effect of group \((F_{2,27} = 4.92, \, P = 0.015)\), with kickers showing a significantly lower motor facilitation \((1.91)\) when compared with goalkeepers \((6.78, \, P = 0.014)\) and novices \((7.12, \, P = 0.012)\). No difference was found between goalkeepers and novices \((P = 0.855)\). ECU MEPs tended to be higher for the later \((5.83)\) than for the earlier \((4.71)\) TMS delays, but the effect did not reach significance \((F_{1,27} = 2.98, \, P = 0.096)\). The main effect of action type and the 2- and 3-way interactions were non-significant \((all \, F < 1)\), thus suggesting that the ECU MEPs were not modulated by incongruence in any group.

**Correlation Between Behavioral and MEPs Data**

The behavioral data in Experiment 2 (see Supplementary
Materials and Fig. 1) mirrored those of Experiment 1. While

| Table 1 | Mean (SD) raw amplitude values (in mV) of MEPs recorded from the GAM, TA, and ECU muscles. |
|---|---|---|
| 1233 ms delay | Congruent | Incongruent | 1300 ms delay | Congruent | Incongruent |
| GAM | | | | | |
| Kickers | 0.7 (0.11) | 0.74 (0.11) | 0.73 (0.1) | 0.69 (0.11) | 0.76 (0.1) | 0.73 (0.09) |
| Goalkeepers | 0.47 (0.07) | 0.64 (0.11) | 0.61 (0.1) | 0.47 (0.07) | 0.63 (0.1) | 0.62 (0.1) |
| Novices | 0.44 (0.07) | 0.52 (0.08) | 0.53 (0.08) | 0.43 (0.06) | 0.56 (0.09) | 0.54 (0.08) |
| TA | | | | | | |
| Kickers | 1.04 (0.17) | 1.18 (0.19) | 1.16 (0.18) | 1.1 (0.18) | 1.24 (0.18) | 1.2 (0.18) |
| Goalkeepers | 0.6 (0.09) | 0.82 (0.13) | 0.77 (0.12) | 0.6 (0.08) | 0.81 (0.12) | 0.78 (0.12) |
| Novices | 0.59 (0.12) | 0.68 (0.11) | 0.71 (0.13) | 0.6 (0.12) | 0.75 (0.13) | 0.72 (0.13) |
| ECU | | | | | | |
| Kickers | 1.05 (0.2) | 1.14 (0.2) | 1.1 (0.22) | 1.02 (0.18) | 1.13 (0.22) | 1.17 (0.21) |
| Goalkeepers | 1.39 (0.25) | 1.74 (0.27) | 1.71 (0.27) | 1.36 (0.25) | 1.8 (0.29) | 1.75 (0.29) |
| Novices | 1.34 (0.35) | 1.61 (0.41) | 1.64 (0.42) | 1.32 (0.38) | 1.59 (0.4) | 1.59 (0.43) |

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kickers and goalkeepers were better than novices in predicting the fate of congruent actions due to their ability to read the body kinematics, novices and goalkeepers were less fooled than kickers by the incongruence between body kinematics and ball trajectory. Thus, we can rule out that previous exposure to the stimuli during the TMS session affected the behavioral performance of participants of Experiment 2, because they had a comparable pattern of responses than that of participants of Experiment 1, who viewed the action video-clips for the first time during the behavioral session.

To explore the relation between cortico-spinal facilitation during observation of incongruent actions and behavioral

![Figure 3. Mean (±SEM) normalized amplitude change of the MEPs recorded in the kicker, goalkeeper, and novice groups in Experiment 2. MEPs were simultaneously recorded from 2 lower limb muscles, namely the GAM (upper graphs) and the TA (middle graphs), and from an upper limb muscle, namely the ECU (lower graphs). TMS pulses were delivered after 1233 and 1300 ms from video-clip onset. MEP amplitude changes are expressed as T-score difference between each observation condition and the baseline, fixation cross condition. Asterisks indicate significant pair-wise comparisons (P < 0.05) between the normalized MEP amplitude change of each group during observation of congruent versus incongruent actions (or at 1233 vs. 1300 ms TMS delays). For the GAM and TA muscles, kickers showed no modulation of MEPs facilitation according to the action type. Goalkeepers showed a reduction, and novices demonstrated an increase in MEP facilitation after presentation of a foot-ball contact that was incongruent with the initial body movements (incongruent actions, 1233 ms TMS delay). The ECU MEP facilitation was lower for kickers than for goalkeepers and novices and, in all groups, tended to be lower for the 1233 ms than the 1300 ms TMS delay. In contrast, no modulation of the ECU cortico-spinal excitability was observed according to the congruence between the kick directions indicated by the body kinematics and the ball trajectory.](image-url)
performance, we computed, separately for the 3 groups, the Pearson correlation coefficients between the MEP facilitation indexes at the 2 TMS delays and the performance accuracy in the corresponding video-clip duration in the behavioral task (Fig. 4). Results showed only a significant negative correlation between the kickers’ TA MEP facilitation index at the 1233 ms TMS delay and their individual accuracy at the 1200 ms video-clip duration ($r = -0.779$, Bonferroni corrected $P = 0.048$). The correlation in the same condition showed a similar trend also for the GAM muscle ($r = -0.706$), although it did not survive the Bonferroni correction procedure. In contrast, the ECU MEPs showed no correlation with the behavioral performance ($r = 0.247$). No significant correlations were found for goalkeepers and novices. Thus, in the kickers’ group, an increased cortical–spinal facilitation of the leg muscles (in particular of the TA muscle) during observation of incongruent body

Figure 4. Correlations between performance accuracy and facilitation of MEPs (expressed as T-score difference from the baseline) during observation of incongruent actions. We tested, separately for each group and muscle, the correlation between the individual accuracy values at 1200 ms video-clip duration and the amplitude changes of MEPs recorded at 1233 ms TMS delay (black points) and between the accuracy values at 1267 ms video-clip duration and the amplitude changes of MEPs recorded at 1300 ms TMS delay (gray points). Only the correlation for the facilitation of the MEPs recorded from the TA muscle of kickers in the 1200 ms video-clip duration/1233 ms TMS delay condition reached the Bonferroni corrected significance threshold. This result indicates a specific, point-by-point association between kickers’ upper limb mirror motor facilitation and their susceptibility to being fooled by bluffing body kinematics. The correlation in the corresponding condition did not survive the Bonferroni correction procedure for the MEPs recorded from the GAM, and there was no correlation found for the ECU.
actions was associated with an increased tendency to be fooled by incongruent body kinematics.

**Discussion**

In the present study, we explored the performance and cortico-spinal reactivity of kickers, goalkeepers, and novices in the task of predicting the fate of incongruent and congruent soccer-specific penalty kicks.

We found that: 1) Kickers and goalkeepers outperformed novices in predicting the fate of the observed actions by reading the body kinematics of the kicking model; 2) kickers were more susceptible than goalkeepers and novices to fake actions where the direction of the kick anticipated from reading body kinematics and the direction indicated by the ball trajectory were incongruent; 3) the different behavioral performance of the 3 groups was reflected in a differential cortico-spinal facilitation of lower limb muscle representations during the observation of incongruent versus congruent actions. In particular, the cortico-spinal reactivity of kickers was comparable for the 2 types of actions but observation of incongruent actions brought about reduced and increased facilitation in goalkeepers and novices, respectively.

**Superior Action Prediction Abilities in Kickers and Goalkeepers When Compared with Novices**

Studies indicate that athletes are able to use body-kinematics cues for predicting the fate of actions in their domain of expertise (Farrow and Abernethy 2003; Abernethy and Zawi 2007; Abernethy et al. 2008; Aglioti et al. 2008; Weissensteiner et al. 2008; Urgesi et al. 2012). Accordingly, kickers and goalkeepers tested in the present study were able to predict the outcome of penalty kick actions after observation of the initial body movements before the foot-ball contact, thus before any ball-trajectory cue was provided.

This type of ability was thought to derive from motor simulation of actions belonging to the athletes’ motor repertoire, implying that motor expertise is more relevant to action prediction than visual expertise (Calvo-Merino et al. 2006, 2010). Only elite basketball players, for example, were able to anticipate the outcome of basketball free shots on the basis of body kinematics alone, whereas coaches, sport journalists, and novices could base their predictions only on the ball trajectory (Aglioti et al. 2008). In a similar vein, adolescents assigned to a volleyball physical practice training improved their perceptual predictions on body kinematics, but not on ball trajectory (Urgesi et al. 2012). Importantly, however, adolescents assigned to an observational practice training improved only in perceiving the ball trajectory (Urgesi et al. 2012). These results suggest that visual and motor experience may play different, complementary roles in action prediction. Visual experience may foster visual representations of actions that are used to describe and to understand the visual dynamics of the actions and of the related contexts (e.g. the ball trajectory). In contrast, motor experience may allow for motor, simulative, body-kinematics-based representations that are used to predict and to anticipate the future actions of other individuals (Wilson and Knoblich 2005; Abernethy and Zawi 2007; Schütz-Bosbach and Prinz 2007; Urgesi et al. 2010; Smeeton and Huys 2011).

That both kickers and goalkeepers were able to predict the outcome of observed penalty kicks on the basis of the initial body movements of the model might stand in contrast with a specific role of motor expertise in shaping action prediction abilities. It is worth noting, however, that previous studies reported a comparable performance of motor and visual experts in fake action detection tasks (Cañal-Bruland and Schmidt 2009; Cañal-Bruland et al. 2010). In these studies, expert field players and goalkeepers outperformed novices in detecting whether a handball player was performing a true or a fake move. However, no difference was obtained between the 2 expert groups independently from their relative level of motor experience. Furthermore, both expert field players and expert goalkeepers were more accurate in predicting actions when viewed from the front than from the side perspective (Cañal-Bruland et al. 2010), notwithstanding that the frontal view is more customary for goalkeepers than players. Thus, the ability of expert players and goalkeepers in predicting domain-specific actions was not specifically predicted by their relative level of motor or visual experience with the actions. Accordingly, we have previously shown that elite athletes outperform novices in body-based predictions of the outcome of actions viewed from both back- and front-facing perspectives (Urgesi et al. 2012). These results are in keeping with neuroimaging and TMS studies showing that although perspective may modulate the activation of fronto-parietal areas during action observation, also passive observation of actions viewed from a third-person, front perspective and not only from a first-person, back perspective engender motor activation (Maeda et al. 2002; Alaerts et al. 2009; Vingerhoets et al. 2012; Wiggett et al. 2012). However, goalkeepers might have not only visual but also motor experience with penalty kick actions. Furthermore, superior perceptual abilities in kickers than goalkeepers may be revealed by more sensitive tasks requiring prediction responses at the earlier action phases (Aglioti et al. 2008), rather than after viewing the full dynamics of body movements before the foot-ball contact as in this study and in previous studies (Cañal-Bruland and Schmidt 2009; Cañal-Bruland et al. 2010).

**Kickers are Highly Susceptible to Fooling Body Movements**

Expert kickers and goalkeepers were able to use body kinematics to create an anticipatory representation of the action outcome. Importantly, however, kickers were more impaired than goalkeepers and even novices in anticipating incongruent kicks on the basis of body kinematics. Such greater susceptibility is unlikely to be due to the kickers’ strategy to respond solely on the basis of body kinematics, while ignoring the information provided by the ball trajectory. Indeed, were this the case, the kickers’ latencies in responding on the basis of body kinematics should be systematically shorter than that of goalkeepers and novices and should not be modulated by the presentation of incongruent or congruent actions. However, response latencies were comparable in the 3 groups and were higher for incongruent actions. Furthermore, the 3 groups improved their ability to detect incongruent actions at longer clip durations indicating comparable task compliance among all 3 groups. This pattern of results suggests that in both the kicker and goalkeeper groups, the initial body kinematics provided enough information to create
an anticipatory representation of the future course of the action. However, while goalkeepers could inhibit and/or update those anticipatory action representations when incongruent contextual cues were presented, the perceptual prediction of kickers remained constrained by the representation based solely on body cues.

Previous studies in different sports have shown that expert players are better than novices in detecting deception cues in others’ body movements (Jackson et al. 2006; Cañal-Bruland and Schmidt 2009; Sebanz and Shiffrar 2009; Cañal-Bruland et al. 2010; Brault et al. 2010, 2012). Effective deception implies: 1) Providing exaggerated body-related cues that induce others to make incorrect action predictions and 2) minimizing or delaying postural cues that may inform others of possible sudden changes (Brault et al. 2010, 2012). It has been shown that unlike novices, experts on body-related cues that honestly signal the actual outcome of the movement and neglect deceptive body-related cues (Brault et al. 2012). This superior ability of experts has been shown both for perceptual judgments and for interceptive actions provided during playing in a virtual reality setting, suggesting its competitive advantage in actual sport performance (Brault et al. 2012).

Because experts are better in reading the body kinematics typical of a given movement, it is not surprising that they outperform novices in detecting body bluffs. Detecting deceptive behaviors, however, may be a challenging task even for experts (Jackson et al. 2006; Sebanz and Shiffrar 2009; Dicks et al. 2010) who may perform like novices (Rowe et al. 2009). Thus, deception may disrupt any expertise-related advantage. Indeed, expert lie catchers (e.g. police officers) who try to detect deception from non-verbal body cues often end up by attributing others’ behaviors to genuine rather than to deceptive intentions (Vrij 2004). Thus, somewhat paradoxically, extensive expertise may, under specific circumstances, produce detrimental results because it does not allow the observer to ignore fooling body kinematics. Such a dark side of expertise may be overcome by basing perceptual judgment on different contextual cues.

In our study, the manipulation between body cues and ball trajectory proved adept at creating a situation in which correct perceptual judgments must be based on contextual, visual cues that index the consequences of the movement in the environment (i.e. ball direction trajectory). Thus, experts with greater motor, rather than visual, expertise turned out to be less skilled in using visual cues for updating motor simulation-based anticipatory representations of others’ actions.

**Goalkeepers Resist Fooling Body Movements**

The greater ability of goalkeepers to resist fooling actions might be due to their visual expertise with frontal-view presentations of kicking players that may allow for more accurate and faster processing of contextual, visual cues (Urgesi et al. 2012). Indeed, although kickers and goalkeepers may have a similar amount of visual experience with penalty kicks, goalkeepers have greater visual familiarity than kickers and novices in front-facing presentations of players kicking a penalty kick and may, thus, use these visual cues to anticipate the model’s actions. However, the performance of goalkeepers in responding to incongruent actions was comparable to that of novices who had no such visual experience.

Therefore, the ability to detect the initial contextual cues provided by the foot-ball contact and the initial ball trajectory does not seem to depend on the level of visual expertise. Importantly, the novices’ unreceptiveness to fooling actions co-existed with their reduced action prediction abilities. Thus, only the goalkeepers were able to shift from a response based on motor simulation of body movements to a response based on the contextual visual cues hinting at their unique flexibility in selective optimal response strategies.

Saving a penalty kick is a complex decision-making task for goalkeepers; it involves not only perceptual and motor abilities, but also cognitive and affective evaluations. Such complexity may induce specific response biases aimed at optimizing the performance, particularly when facing fooling actions (Bar-Eli et al. 2009). In a study of handball actions (Cañal-Bruland and Schmidt 2009), for example, goalkeepers and field players were comparably better than novices in discriminating fake and true actions; however, only goalkeepers were biased to judge observed actions as fake. Similarly, it has been shown that expert soccer goalkeepers tend to wait more than novice goalkeepers before initiating a response and to respond more on the last part of the kicker’s leg kinematics before the foot-ball contact rather than on the initial running phase (Savelsbergh et al. 2002; Dicks et al. 2010). Indeed, possible alterations of the kick direction may occur until 174 ms before the foot-ball contact (van der Kamp 2006). Thus, extensive specific training may allow expert goalkeepers to build an initial anticipatory representation of the action on the basis of the kicker’s movements, but to inhibit or update their simulative representation on the basis of possibly incongruent foot-ball contact and ball-trajectory cues.

**Modulation of Motor Facilitation Predicts Susceptibility to Fooling Body Movements**

An entirely novel result of the present study is the tight functional relation between the different perceptual performance of motor and visual experts and novices and the modulation of cortico-spinal facilitation during the observation of incongruent versus congruent actions.

The 3 groups showed a comparable level of cortico-spinal motor facilitation of lower limb muscles. This result indicates that our action observation task elicited motor activation, an effect which is thought to reflect motor simulation (Fadiga et al. 2005; Avenanti et al. 2007, 2012; Avenanti and Urgesi 2011). Previous studies indicate that cortico-spinal facilitation is specific for the muscles involved in the execution of the observed actions (Fadiga et al. 1999; Romani et al. 2005; Urgesi et al. 2006) and is also modulated by the semantic meaning of the specific action domain (Candidi et al. 2010; Liuza et al. 2011). Also, in a previous study, we found comparable motor facilitation of hand and forearm muscles during observation of basketball actions in athletes, sport journalists, coaches, and novices, suggesting that the motor activation during action observation is partially independent from domain-specific expertise (Aglioti et al. 2008). Importantly, however, motor facilitation of expert athletes and watchers was higher for basketball than for soccer actions, hinting at the effect of motor or visual expertise. Only in elite athletes was the cortico-spinal reactivity different for successful versus erroneous basketball shots, a result that suggested motor, but not visual, expertise allowed a fine tuning of motor activation.
according to the specific kinematics pattern of observed actions (Aglioti et al. 2008).

The kicker, goalkeeper, and novice groups of the present study showed a comparable motor facilitation during the observation of soccer penalty kicks. However, kickers showed a lower facilitation of the forearm muscle when compared with the other groups, suggesting that while novices and visual experts presented a widespread activation of lower and upper limb muscle representations, the kickers’ motor facilitation involved more selectively the representations of the muscles that are used to perform soccer actions.

Importantly, only in kickers, we found a strong negative correlation between motor facilitation and perceptual performance for early-incongruence fake actions. This result suggests a clear link between the kickers’ greater susceptibility to foiling body kinematics and the lack of modulation of cortico-spinal reactivity for incongruent versus congruent actions. The association between reduced motor facilitation contingent upon the observation of incongruent versus congruent actions and the greater ability exhibited by goalkeepers to update their anticipatory action representation with information coming from their observation of the ball trajectory is also relevant. This reduction in cortical excitability may reflect the inhibition of the motor representations formed during observation of the initial body movements.

The few studies on the neural correlates of detecting fooling actions emphasize the importance of non-verbal behavior in revealing fooling behaviors (Ekman and O’Sullivan 1991; Frank and Ekman 1997). Moreover, the request to detect deceptive intentions in an actor lifting boxes of different apparent weights brought about increased activity in the amygdala and anterior cingulate cortex when subjects judged that the actions of others reflected deceptive intentions (Grezes et al. 2004). However, comparing fooling versus genuine actions revealed activation also in the medial frontopolar cortex, superior temporal sulcus, temporoparietal junction, and inferior frontal gyrus (Grezes et al. 2004). Thus, detecting others’ deceptions may be based on capturing subtle differences between genuine and fooling movements and it may require the involvement of the inferior frontal gyrus (Pobric and Hamilton 2006; Avenanti and Urgesi 2011). Several studies have, indeed, shown that motor facilitation is increased during the observation of erroneous actions (Manthey et al. 2003; van Schie et al. 2004; Aglioti et al. 2008; Koelewijn et al. 2008), likely reflecting the discrepancy between anticipated and perceived action kinematics (Wolpert et al. 2003).

Detecting the violations of predicted action patterns, however, may allow us to understand that the actor is deceiving, but it does not allow us to predict the actual course of ongoing actions. Predicting fooling actions may require the prompt inhibition of the action representations triggered by incongruent movements and their updation based on different contextual cues. Thus, while the novices’ increased motor facilitation when observing incongruent versus congruent actions may be related to their perception of incongruent action dynamics at the foot-ball contact, the somatotopic reduction in motor facilitation in goalkeepers may reflect their ability to inhibit the anticipatory motor simulation triggered by the initial body movements. This ability may derive from a refinement of the goalkeepers’ response strategy during their explicit training to save the goal under uncertain circumstances (as in penalty kick actions) and may be linked to the activity of the prefrontal cortex, which is involved in response selection and inhibition during production and perception of fooling behaviors (Grezes et al. 2004; Abe 2009).

In conclusion, the results of the present study suggest that a complex pattern of inhibitory and excitatory processes within the motor system underlies the ability to detect others’ fooling actions. The balance between these processes is modulated by the motor and visual experience of the observers as well as by their learning optimal decision-making strategies. Future studies are needed to outline the involvement and reciprocal interactions between motor and visual areas in the ability to anticipate the true outcome of fake actions.

Supplementary Material
Supplementary material can be found at: http://www.cercor.oxfordjournals.org/.

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Notes
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