Author accepted manuscript

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Published in:
Quarterly Journal of Experimental Psychology

DOI:
10.1177/1747021820945270

Publication date:
2020

Document Version
Peer reviewed version

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Journal:	*Quarterly Journal of Experimental Psychology*
Manuscript ID	QJE-STD-19-257.R2
Manuscript Type:	Standard Article
Date Submitted by the Author:	06-Jul-2020

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Keywords:	embodied cognition, motor priming, person memory, predictive processing, social perception

 DOI: 10.1177/1747021820945270

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Predictive person models elicit motor biases: the face-inhibition effect revisited

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Total word count: 8026 (excluding abstract, figure captions & references)

Key words: embodied cognition, motor priming, person memory, predictive processing, social perception

Acknowledgements: This research was supported by a PhD grant from Plymouth University to Kimberley Schenke and by the Economic and Social Research Council grant [ES/J019178/1] awarded to Patric Bach.

Disclosure of interest: The authors report no conflicts of interest

 DOI: 10.1177/1747021820945270

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Abstract

Using an established paradigm (Bach & Tipper, 2007; Tipper & Bach, 2010), we tested whether people derive motoric predictions about an actor's forthcoming actions from both prior knowledge about them, and the context in which they are seen. In two experiments, participants identified famous tennis and soccer players using either hand or foot responses. Athletes were shown either carrying out or not carrying out their associated actions (swinging, kicking), either in the context where these actions are typically seen (tennis court, soccer field) or outside these contexts (beach, awards ceremony). Replicating prior work, identifying non-acting athletes revealed the negative compatibility effects: viewing tennis players led to faster responses with a foot than a hand, and vice versa for viewing soccer players. Consistent with the idea that negative compatibility effects result from the absence of a predicted action, these effects were eliminated (or reversed) when the athletes were seen carrying out actions typically associated with them. Strikingly, however, these motoric biases were not limited to In-Context trials but were, if anything, more robust in the Out-of-Context trials. This pattern held even when attention was drawn specifically to the context (Experiment 2). These results confirm that people hold motoric knowledge about the actions that others typically carry out and that these actions are part of perceptual representations that are accessed when those others are re-encountered, possibly in order to resolve uncertainty in person perception.

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Predictive person-models elicit motor biases: the face-inhibition effect revisited

Social interactions are highly dynamic and ambiguous. Yet, they require us to rapidly make sense of the internal mental states that drive others' behaviour and respond to them appropriately. Motoric accounts of social perception solve this problem by assuming that others' behaviour is directly mapped onto the observer's own motor system, so that the associated internal states can be accessed and the behaviour can be understood "from the inside" (e.g., Rizzolatti, Cattaneo, Fabbri-destro, & Rozzi, 2014; Giacomo Rizzolatti & Sinigaglia, 2010; Wilson & Knoblich, 2005). Mirror neurons – which fire both when we perform an action, and when we merely observe someone else perform that same action – are assumed to be a central mechanism in this mapping, directly matching incoming kinematic features to corresponding motor programs in the observer (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996).

The robust motoric activation present in behavioural and neuroimaging studies of human action observation (for reviews, see Cracco et al., 2018; Naish, Houston-Price, Bremner, & Holmes, 2014; Oosterhof, Tipper, & Downing, 2013) has been taken as support of this view. For example, simply seeing someone lift a finger facilitates the same finger lift by the observer (Brass, Bekkering, Wohlschlager, & Prinz, 2000; Stürmer, Aschersleben, & Prinz, 2000; for a review, see Cracco et al., 2018). Similarly, viewing someone act with their hand (e.g., typing on a keyboard) or foot (e.g., kicking a football) speeds up the participants' responses with the same body parts (e.g., Bach & Tipper, 2006; Bach, Peatfield, & Tipper, 2007; Gillmeister, Catmur, Liepelt, Brass & Heyes, 2008).

More recently, it has recently been argued that the ambiguity inherent in perceptual input cannot be resolved by such simple bottom-up mechanisms, even in low-level, non-social vision where the mapping is much simpler (e.g., Clark, 2013; Yuille & Kersten, 2006). The

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same social stimulus (e.g., a smile) can have different meanings in different situations (e.g., a polite, happy, or sad smile), and the same internal state can express itself through different behaviours (e.g., experiencing anger can result in either aggressive or avoidant behaviour). More recent approaches therefore cast social perception as a top-down process of hypothesis-testing and revision, in which prior action expectations – derived from various contextual cues, such as facial expressions, nearby objects, or verbal statements – are tested against others' actual behaviour (e.g., Bach, Nicholson & Hudson, 2014; Bach & Schenke, 2017; Hickok, 2009; Kilner, Friston, & Frith, 2007a; Liepelt et al., 2009). In such predictive processing accounts, the robust motor activation during action observation reflects not a bottom-up matching of observed behaviour to own motor representations, but instead an attempt to *predict* the other's most likely action and to test it against what was actually observed (e.g., Hickok, 2009; Kilner et al., 2007; Csibra, 2008; Bach, Nicholson & Hudson, 2014). Recent studies provide direct evidence for such predictions, showing, for example, that attributing goals to others induces predictive perceptual biases in action identification and perceptual judgments (Hudson et al., 2016[ab]; 2017, 2018; McDonough, Hudson, & Bach, 2019; Schenke et al., 2016; see Bach & Schenke, 2017, for a review). Moreover, consistent with motor prediction views, the well-documented motor activation during action observation can reflect actions that are expected but not (yet) observed (Avenanti, Annella, Candidi, Urgesi, & Aglioti, 2013), even on the level of single neurons (Maranesi, Livi, Fogassi, Rizzolatti, & Bonini, 2014; Urgesi et al., 2010). It is sensitive to the (inferred) goal of the action (Liepelt et al., 2009), and is strongest for actions compatible with goal achievement (e.g., Bach, Bayliss & Tipper, 2011).

So far, most research to date has investigated how action predictions are derived from overt cues: the objects surrounding the actor, their gaze, facial expressions or overt intention statements (e.g., Bach, Nicholson & Hudson, 2014; Adams, Ambady, Macrae, & Kleck,

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2006; Bach et al., 2011; Hudson, Nicholson, Ellis, & Bach, 2016; Hudson, Nicholson, Ellis, & Bach, 2015; Hunnius & Bekkering, 2010; Johnston, Miles, & Macrae, 2010; Pierno et al., 2006; Stapel, Hunnius, & Bekkering, 2012). Recently, we and others have argued that the *identity* of the actors themselves could make an important contribution as well (Bach & Schenke, 2017; Schenke, Wyer & Bach, 2016; Barresi & Moore, 1996; Newen, 2015). Humans form sophisticated internal models of how other people behave in different situations, such as which toy our child typically picks, or which wine our spouse prefers (e.g., Schenke et al., 2016; Barresi & Moore, 1996; Newen, 2015; Monroy, Meyer, Gerson & Hunnius, 2017; Buchsbaum, Gopnik, Griffiths, & Shafto, 2011). As soon as such models are established, they can support social interactions by providing information about which actions will be carried out by an individual when they are encountered again in the same situation. Consistent with this view, studies have shown, for example, that people's attention is automatically biased towards the object someone *usually* looks at rather than where they are actually looking (Joyce, Schenke, Bayliss, & Bach, 2015). Moreover, people are faster to identify an action that is typically carried out by one person in a given situation, compared to an action that is typically carried out by someone else (Schenke et al., 2016), and they unconsciously learn another player's idiosyncratic "tells" that predict their actions in gambling (Heerey & Velani, 2010).

Here, we examine whether the activation of internal person models can be tracked not only by perceptual measures, but by motoric activation as well. This hypothesis follows from the idea that people embody their action knowledge of the other person, using their own motor system to *predict* the other person's forthcoming actions (e.g., Csibra, 2008; Kilner et al., 2007ab; Bach et al., 2014; Schenke & Bach, 2017). Prior work from ourselves and others (Bach and Tipper , 2006; Tipper & Bach, 2011; Candidi, Vicario, Abreu, & Aglioti, 2010; Sinnett, Hodges, Chua, & Kingstone, 2011) provides suggestive evidence for just such an

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effect. In these studies, participants were asked to identify famous soccer and tennis players from their faces with hand or foot responses. The results revealed a negative compatibility effect between the foot and hand responses required of the participant and the hand and foot-centric sports of the athletes. That is, participants responded more slowly with their own hand when identifying tennis players than soccer players and more slowly with their own foot when identifying a soccer than a tennis player. According to predictive processing views, these negative compatibility effects may index a prediction error: the activation of a predicted action that cannot be matched to the actual sensory input in the photographs that showed non-acting athletes. Indeed, the effects reversed (i.e., turned into positive compatibility effects), when, in a later study, the same athletes were shown carrying out the actions they are known for (hitting a tennis ball or kicking a football; Tipper & Bach, 2011).

Here, we test whether this actor-specific modulation of motor output reflects the activation of person-specific internal models for action prediction. One key signature of such person models is that they should not just generally capture the actions that others' typically carry out, but also the situations in which these actions are typically seen in (Bach & Schenke, 2017; Barresi & Moore, 1996). In our case, for example, participants should not only predict that Ronaldo generally kicks a ball, but that he would do so specifically when he is seen on the soccer pitch (but not, say, on the beach). Similarly, a famous tennis player should only be predicted to use the racket on, but not off, the tennis court. Thus, if positive and negative compatibility effects reflect successful and unsuccessful motoric predictions from such situation-specific person models, they should be observed primarily when the athletes are seen in their sporty contexts but less so in neutral contexts where these actions are not expected. This hypothesis has not yet been directly tested in any of the previous studies. For example, while Tipper and Bach (2010) showed acting or not-acting athletes, they did not manipulate whether they were seen within or outside their sports contexts. In contrast, Bach

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& Tipper (2006) did manipulate context, but mostly to increase variability of the stimuli, and only showed not-acting athletes. Moreover, as the stimuli showed mostly the athletes' faces, the sporty and neutral contexts were not salient and no differential compatibility effects were observed.

Here, we report two experiments that adapted the original design to directly test the predictions outlined above. As before, we presented participants with various images of four famous athletes – two tennis players and two soccer players – either carrying out their usual sporting actions (kicking a football, hitting a tennis ball with a racket) or showing them in a neutral pose not related to these behaviours. In a fully factorial design, we varied independently whether these athletes were seen within their typical contexts (e.g., on the tennis court or soccer pitch) or outside those contexts (e.g., at an awards ceremony or at the beach). Participants again identified these athletes using either a finger or foot key press, such that for each participant, one tennis and one soccer player had to be identified with the foot, and the other two athletes with the hand.

This design enables us to confirm, first, whether the athletes' typical behaviour is an embodied component of the observer's person knowledge that is matched against the behaviour that is observed. If so, then, just as in prior research, identifying the famous athletes should induce compatibility effects in opposite directions depending on whether the athletes are seen acting or not-acting: Athletes that are carrying out their usual behaviour should elicit *positive* compatibility effects; they should be identified more quickly with a body part that matches these typical behaviours (e.g., faster foot responses to identify a footballer that a tennis player, and vice versa for hand responses, Bach et al., 2007; Bach & Tipper, 2006; Gillmeister et al., 2008). In contrast, athletes that are seen not-acting should elicit *negative* compatibility effects. They should be identified *more slowly* with the body part

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that matches their usual motor behaviour, indexing the unexpected absence of these actions (Bach & Tipper, 2006; Tipper & Bach, 2010).

Second, and more importantly, this design allows us to test the novel hypothesis, derived from predictive person model accounts, that these motoric predictions reflect the actions that actors are expected to carry out in a specific situation. If so, then the motoric modulation should be sensitive to the context in which the athletes are observed: both positive and negative compatibility effects should be stronger when the actors are seen in their typical sporty contexts – the soccer field and tennis court – where these behaviours are expected, but less so in more neutral contexts in which they are not.

The current findings will help test predictive person model accounts against competing theories. For example, in associative accounts (Heyes, 2010; Keysers & Perrett, 2004; Hommel, Müsseler, Aschersleben & Prinz, 2001; Hommel, 2019), motor activation during action observation reflects domain-general learning processes that have associated one's motor behaviours to the perceptual effects that reliably go along with them, rather than attempts to test predictions against the perceptual input. Such associative learning mechanisms readily account for the positive compatibility effects elicited by the different athletes, and potentially also by their tennis- and soccer-contexts, as these could simply be linked to the initial motor-action representations via spreading activation. However, they have a hard time accounting for the negative compatibility effects that emerge when the athletes are seen not-acting: if athletes have been associated with different motor behaviours, then these behaviours should be activated – but not inhibited – when the athletes are seen again, even when the actions themselves are not part of the stimulus display.

Another possibility is that actor-related motor activations do not reflect predictions of a specific action in a given situation, but instead reflect more general predictive person

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knowledge that is not linked to a particular context. For example, from watching the athletes play, we might have formed rather general links between them and their typical behaviour: that Rooney and Ronaldo typically kick soccer balls and that Federer and Murray typically hit tennis balls with their rackets, irrespective of whether they are in or out of their sporty contexts. Later on, when re-encountering the athlete, we might rely on these general action expectations to confirm that it is really them that we are seeing. If this were the case, then the positive and negative compatibility effects should be insensitive to the current situation and be observed both when the athletes are seen in their sporting contexts and outside of it. In fact, it could even be the case that such motoric knowledge is recruited particularly when people are seen *outside* their usual context. Encountering someone out of their usual context (e.g., running into one of your students at the supermarket) produces surprise and uncertainty. This uncertainty may, in turn, draw attention and lead to the recruitment of additional processing – including activating the actions the individuals typically carry out – to make sense of the novel situation (e.g., Bar, 2003; Fenske, Aminoff, Gronau, & Bar, 2006; Reichardt, Polner, & Simor, 2020). Context should then have the opposite effects than those assumed by predictive person models: positive and negative compatibility effects should be stronger, not weaker, whenever the athletes are seen outside their usual contexts.

Experiment 1

Experiment 1 tested whether participants' motor systems represent the merely predicted (but not observed) actions of other people, based on our prior knowledge of them. Participants were presented with photographs of famous soccer (Wayne Rooney, Cristiano Ronaldo) and tennis (Andy Murray, Roger Federer) players either acting, or not acting, in a neutral context

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or in their usual sports context, in a fully counterbalanced factorial design. Participants had to identify these athletes with hand and foot responses, such that one tennis player (e.g., Andy Murray) and one footballer (e.g., Wayne Rooney) had to be identified with a foot response, and the others (e.g., Roger Federer and Cristiano Ronaldo) with a hand response.

The goal of Experiment 1 was, first, to replicate the finding that identifying famous athletes interferes with participants' ability to use the body part used in their sport when they are seen not acting (i.e., the face inhibition effect, Bach & Tipper, 2006), but facilitates similar motor output when they are seen carrying out the expected actions (Tipper & Bach, 2011). Second, and more importantly, it tested whether these effects reflect underlying person models that predict others' behaviour in different situations. If so, then these effects should be context-specific: both the negative and positive compatibility effects should be stronger when the athlete is in their sporty situation (e.g., on a soccer pitch), where such an action is expected, but not in a neutral situation (e.g., at the beach), where these actions are less likely to be seen.

Method

Participants

43 participants (34 female, mean age = 20.86 years, SD= 4.49; 38 right-handed) took part in exchange for course credit. They were recruited based on their self-reported ability to recognise the four athletes. All participants provided written consent. The experiment was approved by the Faculty of Health and Human Sciences Research Ethics Committee at the University of Plymouth prior to data collection [reference number: 14/15-320]. We report all measures, manipulations and exclusions for both experiments. Sample size matched prior studies on this effect (Bach & Tipper, 2006; Tipper & Bach, 2011; Sinnett et al., 2011). Four

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participants had technical difficulties with the foot pedal and were excluded from the analysis. The final sample size provides 80% power to detect medium effect sizes in the predicted direction with $d > .405$, and in either direction with $d > .460$, as determined with a sensitivity analysis using G-Power (Erdfelder, Faul, Lang, & Buchner, 2007). The smallest effect sizes of interest (SESOI; Lakens, Scheel, & Isager, 2018) given the sample size and test are $d = 0.324$ (two-sided) and $d = 0.270$ (one-sided).

Materials and apparatus

The experiment was administered with E-prime 2.0 (Psychology Software Tools, Pittsburgh, PA), running on an Intel i3 CPU, 4GB Memory, 500GB HDD, Windows 10 Professional with a Philips Brilliance 221P monitor set to a resolution of 1024 by 768.

The stimulus set consisted of 32 photographs of four athletes: two well-known soccer players (Wayne Rooney, Cristiano Ronaldo) and two well-known tennis players (Andy Murray, Roger Federer). Each of the four athletes were shown in two photographs for each of the four conditions that resulted from the factorial combination of In-Context and Out-of-Context scenes and acting or not-acting athletes (see Figure 1 for examples). The photographs were sourced from a Google image search and selected such that they showed the athletes' full body with the face easily identifiable. The In-Context photos showed soccer players on the soccer field and tennis players on the tennis court, wearing their usual sports attire. The Out-of-Context images showed the four athletes in any situation other than a tennis court or soccer field, such as at an awards ceremony, a photo shoot, or on the beach. The images were of varying sizes (between 328 and 522 pixels vertically and 169 to 483 pixels horizontally). To prevent laterality effects (Simon, 1969), all images were presented centred in the middle of the screen and each photograph was cropped so that the athlete filled the whole photograph

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from left to right, with the identification-relevant features of body and face centred as much as possible (see Supplementary Materials for the full stimulus set).

--- Insert Figure 1 about here ---

As in Bach and Tipper (2006), a post-experiment questionnaire asked how often participants had seen each athlete playing tennis/football, how skilled they thought the athlete was compared to other professionals within their sport, how talented they thought the athlete would be at the other sport (e.g., for Andy Murray, participants were asked how talented they thought he would be at football), and finally how much participants liked each athlete. Each question was answered on an 8-point Likert scale from -4 to +4 with no zero point.

The social intelligence scale (Silvera, Martinussen, & Dahl, 2001) was administered to test correlations between self-report measures of social intelligence and response time effects. However, as there were no statistically reliable correlations for either the negative or positive compatibility effects, this will not be discussed further.

Procedure

Each trial started with a fixation point in the centre of the screen for between 800 and 1000 ms (randomly chosen) followed by the photograph of one of the athletes in one of the conditions. This image disappeared as soon as a response was given, up to a maximum interval of 2000 ms. Participants were instructed to identify the athletes as quickly and as accurately as possible. One soccer player and one tennis player had to be identified by

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pressing the foot pedal, and the second soccer player and tennis player had to be identified by pressing a key on the keyboard, with the response assignment counterbalanced across four groups of participants. If participants responded correctly, they were shown a blank screen for 300 ms. If not, or if they responded too late, they were given a reminder of which response to use for each athlete for 3000 ms.

As in the prior studies (Bach & Tipper, 2006; Tipper & Bach, 2011) participants were asked to respond with the right hand and the right foot to press centralized response devices. Such a response setup should further safeguard against (Simon-like) laterality effects affecting the results, as such effects are only observed when there is differential lateralization in *both* stimuli and response alternatives (Dolk et al., 2014; Hommel, 1996; Sebanz, Knoblich & Prinz, 2003). In contrast, here, participants responded to centrally presented images (see Stimuli) with two responses that were equally right-lateralized and therefore only differed in whether they involved a foot or hand movement; they should therefore not induce lateralized response effects.

Participants completed 384 trials in total – 12 blocks of the 32 photographs presented in random order. After six blocks, participants were given the opportunity for a break. After the experiment was completed, participants filled out the exit questionnaire and the social intelligence scale and were debriefed and thanked for their participation.

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Results

Response times

Trials were excluded if they had RTs greater than the trial duration, and if they had RTs greater than three SDs from their condition mean (1.65%). For the analysis of RTs, error trials were additionally excluded (4.79%). The remaining data were averaged by condition for each participant and analysed with a repeated measures ANOVA with the within-subjects factors Context (In-Context, Out-of-Context), Action (Action, Non-Action) and Effector Congruency (congruent with the athlete's typical effector, incongruent with the athlete's typical effector). Group (Rooney/Murray hand and Ronaldo/Federer foot, Rooney/Murray foot and Ronaldo/Federer hand, Ronaldo/Murray hand and Rooney/Federer foot, Ronaldo/Murray foot Rooney/Federer hand), was added as a between subjects factor of no interest to account for variability due to one of the four counterbalancing conditions (which of the tennis/soccer players were identified with the hand and which with the foot).

We predicted that the ANOVA would replicate the two-way interaction of Action and Effector Congruency observed in prior research (Bach & Tipper, 2006; Tipper & Bach, 2011), reflecting that seen and merely predicted actions bias observers' motor systems in the opposite direction, inducing positive and negative compatibility effects, respectively. In addition, we expected compatibility effects to be larger when the athletes are seen in their usual contexts, reflected in a three-way interaction of Context, Action and Effector Congruency. These predicted results will be evaluated against the usual alpha of $p < .05$ (two tailed). Due to alpha-inflation linked to multiple testing in an ANOVA (Cramer et al., 2016), the five other possible main effects and interactions should be evaluated with caution unless they meet a Bonferroni-corrected alpha threshold of $p <.01$ (see Supplementary Materials for a table of the full output).

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As in the original studies (Bach & Tipper, 2006; Tipper & Bach, 2011), the analysis of the response time data revealed the predicted interaction of Action and Effector Congruency, $F[1,35] = 5.580$, $p = .024$, $\eta\rho^2 = .138$. Planned comparisons for the Action and Non-Action trials separately (with Group as a factor of no interest) revealed that this difference mainly reflected that, in the Non-Action trials, responses were slower for Congruent than Incongruent trials, $F[1,35] = 5.410$, $p = .026$, $\eta\rho^2 = .134$, replicating the face-inhibition effect. However, while the Action trials numerically showed the predicted positive compatibility effect, the difference between Congruent and Incongruent responses was not robust, $F[1,35] =1.251$, $p =.306$. The predicted three-way interaction of Context, Action and Effector Congruency was not significant, $F[1,35] = .048$, $p = .827$, $\eta\rho^2 = .001$. Indeed, when In-Context and Out-of-Context trials were analysed separately in planned comparisons, the crucial interaction of Action and Effector Congruency was, if anything, more robust in the Out-of-Context trials, $F[1,35] = 3.834$, $p = .058$, $\eta\rho^2 = .099$, than the In-Context trials, $F[1,35] = 1.241$, $p = .273$, $\eta\rho^2 = .034$, contrary to our predictions.

Aside from these confirmatory hypothesis tests, the ANOVA only revealed a theoretically uninteresting main effect of Context, $F[1,35] = 80.740$, $p < .001$, $\eta\rho^2 = .698$, with faster response times for identification of athletes Out-of-Context than In-Context, as well as a main effect of Action, $F[1,35] = 9.278$, $p = .004$, $\eta\rho^2 = .210$, with faster responses when athletes were seen performing their action compared to when they were not acting. As in the original study, these differences probably reflect low-level differences in the stimuli in these conditions but are independent of our main results. There was no main effect of Effector Congruency, $F[1,35] = 1.111$, $p = .299$, $\eta\rho^2 = .031$.

--- Insert Figure 2 about here ---

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Error rates

An analogous ANOVA as for the response time was carried out on the error rates (see Table 1) but revealed no theoretically relevant effects.

--- Insert Table 1 about here ---

Correlations with subjective ratings

In the study of Tipper and Bach (2011), the positive compatibility effects when the athletes were seen acting, but not the negative compatibility effects when the athletes were seen not carrying out these actions, correlated with participants' familiarity with the athletes and their evaluation of their skills, with positive compatibility effects being larger for participants that were very familiar with the athletes and judged their skills highly. No correlations were observed with assessments of the athletes' respective other sport (e.g., tennis for Ronaldo), nor for how much the athletes were generally liked. Exactly this pattern was observed here (see Supplementary Materials for a table of the full results). The positive, but not the negative, compatibility effects correlated with the familiarity of the athletes (r=.331, p = .040) and assessments of their skill (r= .381, p = .017), but not with the other measures (r < .180).

Discussion

Experiment 1 tested whether seeing a famous athlete elicits a motoric expectation that they would carry out their sporting actions, and whether these expectations depend upon whether the athlete is seen within or outside his usual sporting contexts. The results replicated

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previous findings that viewing famous athletes influences the observer's motor systems (Bach & Tipper, 2006; Tipper & Bach, 2011) in a completely new stimulus set. As before, identifying the athletes when they were not-acting elicited negative compatibility effects. Participants responded more slowly when identifying the tennis player Andy Murray with a hand compared to a foot response, for example, and vice versa for the soccer player Cristiano Ronaldo. Moreover, as in Tipper and Bach (2011), these negative compatibility effects were eliminated – and turned numerically into positive compatibility effects – when participants identified the athletes performing their typical actions, in line with the idea that the negative compatibility effects index a prediction failure: the surprising absence of an action that the athlete would have been expected to carry out.

Contrary to the predictions of situation-specific internal person models, Experiment 1 did not provide evidence that these positive and negative compatibility effects would be stronger when the athletes were seen in their usual sporty context, where they would be most likely to execute these expected actions. If anything, while this was not supported by a robust statistical difference, effects were larger and more reliable when the athletes were seen *outside* their usual sporting contexts, potentially in line with the idea that seeing the athletes in unexpected environments draws attention and recruits additional action knowledge about them.

One reason for the absence of a reliable difference might be that the context manipulation was not strong enough to induce detectable effects within the current paradigm. The relevant context may not have been salient enough, and may be activated too late, to influence responses. Therefore, in Experiment 2, each athlete image was preceded with a short preview of the context they would be presented with in the next critical image.

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Experiment 2

Experiment 2 sought to enhance the availability of context information in order to more clearly delineate the conditions most likely to produce positive and negative compatibility effects. It therefore provided photographs of the contexts in which the athlete would later be seen (a tennis court, soccer pitch, or one of two beach scenes) for 500 ms. prior to the critical athlete photograph. As before, the following photograph then showed one of the four athletes either carrying out their specific action (kicking or playing tennis) or not carrying out this action in an unusual situation or in their usual sporty context. Participants identified the athletes with a foot or hand response which was either congruent or incongruent with the expected or observed action of the athlete.

As before, we hypothesized that any motoric expectancy effects should be stronger when the athlete is seen in their typical situation (e.g., on a soccer pitch), where they would be expected to perform these actions, compared to a situation, where such an action would be less expected (e.g., at the beach). Thus, the In-Context trials should show that identifying famous athletes interferes with participants' ability to use the body part primarily used in their sport when they are seen not acting, but facilitates similar motor output when they are seen carrying out the expected actions (Bach & Tipper, 2006; Tipper & Bach, 2011). These effects should be absent or reduced when the athletes are seen outside their usual sporty contexts.

Method

Participants

56 participants (35 female, mean age = 21.29 years, SD = 5.28; 49 right-handed) took part in the study in exchange for course credit. All other aspects of the participant selection were

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identical to Experiment 1. Sample size was increased relative to Experiment 1 to be able to detect potentially smaller effects. This sample size provides 80% power to detect medium effect sizes in the predicted direction with $d > .336$, and in either direction with $d > .381$, as determined with a sensitivity analysis using G-Power (Erdfelder et al., 2007), in line with the effect size of the Action by Effector Congruency interaction observed in Experiment 1 ($d = .358$). The smallest effect sizes of interest (SESOI; Lakens, Scheel, & Isager, 2018) given the sample size are $d = 0.268$ (two-sided) and $d = 0.224$ (one-sided).

Materials, apparatus and procedure

The experiment was identical to Experiment 1 except that an additional 'priming' photograph of either a beach scene or a tennis/soccer scene was now presented for 500 ms prior to the critical photograph, 509 and 512 pixels wide and 396 and 384 pixels tall. There were four priming photographs altogether, two showing non-sports environments (two different beach scenes) for priming the Out-of-Context images, and two showing the two (tennis and soccer) sports environments for priming the In-Context images. To ensure that the Out-of-Context scenes were as predictive of the subsequent athlete type as the In-Context scenes, one of the beach scenes always preceded tennis players and one always preceded soccer players. In addition, all Out-of-Context photographs now showed the actors on the beach.

--- *Insert Figure 3 about here* ---

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Results

Response times

Trials were excluded as before (5.29% for error trials, 1.83% for scores greater than 3 SD from the mean). The remaining data for each participant were averaged by condition and analysed with a repeated measures ANOVA with the factors Context (In-Context, Out-of-Context), Action (Action, Non-Action) and Effector Congruency (congruent with the athlete's typical effector, incongruent with the athlete's typical effector) with Group (Rooney/Murray hand and Ronaldo/Federer foot identification, Rooney/Murray foot and Ronaldo/Federer hand identification, Ronaldo/Murray hand and Rooney/Federer foot identification, Ronaldo/Murray foot Rooney/Federer hand identification) included as a between subjects factor of no interest.

As in Experiment 1, we predicted a two-way interaction of Action and Effector Congruency (Bach & Tipper, 2006; Tipper & Bach, 2011) and/or a three-way interaction of Context, Action and Effector Congruency. Due to alpha-inflation linked to multiple testing in an ANOVA (Cramer, 2016), the five other possible main effects and interactions should be evaluated with caution unless they meet a Bonferroni-corrected alpha threshold of p <.01 (see Supplementary Materials for a table of the full output).

Replicating Experiment 1, and previous experiments (Bach & Tipper, 2006; Tipper & Bach, 2011), the analysis of response times revealed the predicted interaction between Action and Effector Congruency, $F[1,52] = 6.531$, $p = .014$, $\eta\rho^2 = .112$. Planned comparisons revealed faster response times when acting athletes were identified with the Congruent compared to Incongruent effector, $F[1,52]= 4.148$, $p = .047$, $\eta\rho^2 = .074$, showing positive compatibility effects. The negative compatibility effect for identifying non-acting athletes seen in Experiment 1, and previous research (Bach & Tipper, 2006; Tipper & Bach, 2011), were

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present numerically but failed to reach significance, $F[1,52]=2.744$, $p = .104$, $\eta\rho^2 = .050$. The predicted three-way interaction was, again, not significant, $F[1,52] = 1.579$, $p = .215$, $\eta\rho^2 = .029$. As before, and contrary to the predictions of situation-specific person models, when Out-of-Context and In-Context trials were analysed separately in planned comparisons, the crucial interaction of Action and Effector Congruency was statistically robust in the Out-of-Context trials, $F[1,52] = 6.748$, $p = .012$, $\eta\rho^2 = .115$, but not in the In-Context trials, $F[1,52] = 1.434$, $p = .237$, $\eta\rho^2 = .027$.

Beyond these confirmatory hypotheses, the analysis only revealed a theoretically uninteresting main effect of Context, $F[1,52] =14.524$, $p < .001$, $\eta\rho^2 = .218$, but no interaction of Action and Context, $F[1,52] = 5.021$, $p = .029$, $\eta\rho^2 = .088$ and no overall main effects of Effector Congruency, $F[1,52] =.016$, $p = .901$, $\eta\rho^2 < .001$ nor of Action, $F[1,52] = .244$, $p = .624$, $\eta\rho^2 = .005$.

--- Insert Figure 4 about here ---

Error rates

The same ANOVA was conducted on the error data but revealed no theoretically relevant effects (see Supplementary Materials and Table 2).

--- Insert Table 2 about here ---

Correlations with subjective judgments

We again tested whether we would replicate the relationships between the positive compatibility effects and participants' subjective judgments seen in prior research (Bach &

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Tipper, 2006) and Experiment 1 (see Supplementary Materials for a table of the full results). Accordingly, we predicted that the positive compatibility effects when the athletes were seen acting, but not the negative compatibility effects when they were seen not acting, would correlate positively with participants' familiarity with the athletes and their evaluation of their skills. However, this pattern was not replicated in Experiment 2 ($r < .187$, for all), which differed in methodology in the use of the priming context images to Experiment 1 and the prior studies.

Discussion

Experiment 2 showed – as in Experiment 1 and previous studies (Bach & Tipper, 2006; Tipper & Bach, 2011) – that viewing famous athletes did influence the observer's motor systems. As before, seeing the athletes act or not-act, produced compatibility effects in opposite directions. Whilst positive compatibility effects were found when the athletes were seen carrying out their sporty activities, they turned (numerically) into negative compatibility effects when the athletes were seen not carrying out these actions. These findings are in line with the idea that people predict the athletes' forthcoming actions, and that these prediction successes and failures are indexed by positive and negative compatibility effects, respectively. However, we could not confirm that these effects were stronger when the athletes were seen in their usual sporty context, where they would be most likely to execute these expected actions. If anything, effects were more reliable when the athletes were seen in neutral contexts. To estimate the evidence for the presence or absence of the relevant effects, a post-hoc exploratory analysis including Bayesian statistics was conducted on the pooled data from both experiments.

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Across-experiment analysis

Both experiments provided evidence that identifying famous athletes modulates the observer's motor system in opposite directions, depending on whether the athletes are seen acting or not acting. However, neither experiment supported the prediction that the resulting positive and negative compatibility effects were larger when the athletes were presented in their usual contexts (e.g., tennis court, soccer field). If anything, the effects were more robust when the athletes were seen *outside* these contexts (e.g., at the beach). In order to estimate the extent to which the combined data provide evidence for – or against – a difference between the two contexts, we conducted an exploratory analysis using both Frequentist and Bayesian analysis methods that combines the data from both experiments for additional power. This combination of both experiments (n=95) provides us with 80% power to detect d=.256 (one-sided) and d=.290 (two-sided), with a smallest effect size of interest of d=.203 (two-sided) and d=.170 (one-sided).

This analysis also allows us to estimate the robustness of the positive and negative compatibility effects. While the overall modulation of motor output when seeing acting or not-acting athletes was robust and present in both experiments, it is not clear whether this mainly reflects (1) positive compatibility effects when the athletes were seen acting, (2) negative compatibility effects when they were seen not acting, or (3) both. While the negative compatibility effects elicited by not-acting athletes were statistically robust in Experiment 1, they were only present numerically in Experiment 2. Conversely, the positive compatibility effects for acting athletes were statistically robust in Experiment 2, but only present numerically in Experiment 1. Combining the data from both experiments will therefore reveal to what extent the data provide evidence for either effect.

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We used the same ANOVA model as in Experiments 1 and 2 and applied it to the pooled data, including the factors Context (In-Context, Out-of-Context), Action (Action, Non-Action) and Effector Congruency (congruent with athlete's typical effector, incongruent with athlete's typical effector) with counterbalancing Group and Experiment added as between-subjects factors of no interest. This ANOVA was run both in Frequentist and Bayesian versions (using JASP, JASP Team, 2018) to robustly estimate evidence for each effect, and then further investigated with step-down analyses.

The omnibus ANOVA confirmed the interaction of Action and Effector Congruency that was present in both experiments, providing considerable evidence that viewing acting or not-acting athletes induces congruency effects in opposite directions, $F[1,87] = 10.66$, $p = .002$, $\eta\rho^2 = .109$, $BF_{10} = 3.954$. Step-down analyses showed that this interaction was mainly driven by the negative compatibility effects when identifying not-acting athletes, $F[1,87] = 8.014$, $p = .006$, $\eta\rho^2 = .084$, $BF_{10} = 2.604$, but not the positive compatibility effects when seeing them act, $F[1,87] = 0.485$, $p = .488$, $\eta\rho^2 = .006$, $BF_{10} = 0.220$.

Most importantly, as in the single experiments, the predicted interaction of this effect with Context was not present, $F[1,87] = 1.33$, $p = .252$, $\eta\rho^2 = .015$, with the Bayesian analysis providing considerable evidence *against* such a three-way interaction, $BF_{10} = .251$. Indeed, planned step-down analyses in each context condition separately revealed considerable to strong evidence for the presence of an interaction of Action and Effector Congruency in the Out-of-Context trials, $F[1,87] = 10.435$, $p = .002$, $\eta\rho^2 = .107$, $BF_{10} = 9.260$, but anecdotal to considerable evidence for its *absence* in the In-Context trials, $F[1,87] = 2.448$, $p = .121$, $\eta\rho^2 = .001$, $BF_{10} = 0.367$.

As the pattern is, if anything, opposite to the hypothesis of situation-specific person models for action prediction we directly compared the contrast values for the critical Action by

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Effector Congruency interaction in the In-Context and Out-of-Context trials against each other with Bayesian t-tests. This allows one to separately evaluate evidence for the directed hypotheses that the motoric modulation is either stronger or weaker in the In-Context compared to the Out-Of-Context trials. This analysis provided strong evidence *against* the hypothesis that the motoric modulation is situation-specific and larger in the In-Context than the Out-of-Context trials, BF_{10}=.06, but may leave some (limited) scope that it may potentially be smaller, BF_{10}=.312.

Together, therefore, this analysis of the pooled data provides evidence for a robust modulation of the observer's motor system when seeing famous athletes not acting, which is – against our predictions – not larger when the athletes are seen in their usual contexts. In fact, the results are mostly driven by seeing these athletes *not* act in Out-of-Context situations.

General discussion

We tested whether person identification involves activating – *predicting* – the actions that an individual typically carries out, and whether these predictions rely on the observer's motor system. In two experiments, participants viewed well-known soccer and tennis players in their typical contexts (soccer field, tennis court) or outside their typical contexts (e.g., on the beach), either carrying out their typical actions or in a neutral posture. Participants identified these individuals by making either foot or hand responses, allowing us to test whether merely identifying these athletes biases the observer's motor system towards the effector typically used in their sport, even if this action is not currently observed.

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Both experiments confirmed that identifying famous athletes modulates the observers' motor systems in opposite directions depending on whether the athletes were seen acting or not-acting (Bach & Tipper, 2006; Tipper & Bach, 2011; Candidi et al., 2010; Sinnett et al., 2011). When the athletes were seen *not carrying out their expected actions* we found the expected negative compatibility effects, such that participants were impaired in using the effector that was primarily used in the seen athlete's sport, as reported previously (Tipper and Bach; 2011; Bach & Tipper, 2006; Candidi et al., 2010). Thus, participants were slower to identify a tennis player (e.g., Andy Murray) with a hand than a foot response, and vice versa for a famous soccer player (e.g., Cristiano Ronaldo). We also replicated – at least in Experiment 2 – the usual automatic imitation ("mirror") responses when the athletes were seen carrying out their usual actions, such that participants more quickly identified a soccer player with a foot response and a tennis player with a hand response (Bach et al., 2007; Gillmeister, Catmur, Liepelt, Brass, & Heyes, 2008; Tipper & Bach, 2011). Note though that this difference was not robust in the pooled data across experiments, consistent with the view that these effects are rarely observed in static displays where no motion draws attention to the observed actions (e.g., Bach et al., 2006).

The observed modulation of the observer's motor system is consistent with our proposal that person identification draws not only upon information about the individual's visual features (e.g., face shape, complexion, etc.) or known traits (Macrae, Quinn, Mason, & Quadflieg, 2005; Quinn, Mason, & Macrae, 2009; Quinn, Mason, & Macrae, 2010), but also information about their expected behaviours (Schenke et al., 2016; Joyce et al, 2015; for theoretical arguments, see Bach & Schenke, 2017; Barresi & Moore, 1996). It implies that these action expectations are represented in an (at least partially) embodied format and are matched against the behaviour that is actually observed, such that seeing the athletes either carry out or not-carry out their expected actions facilitates or impairs the use of the relevant body part in

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the observer. Such a reversal is not consistent with the idea that the compatibility effects reflect mere associations of athletes to motor behaviours, which would have been independent from the athletes' actual behaviour. Instead, it implies that the positive and negative compatibility effects reflect either successful or unsuccessful attempts to match these prior action expectations to the behaviour that was indeed observed.

Strikingly, this opposite modulation of the motor system was not larger when these athletes were seen in their usual contexts. We had hypothesized that any action expectation should be strongest when the athletes are seen in situations in which these actions are most likely to occur – on the soccer field or the tennis court – and weaker outside these contexts. However, neither of the experiments provided evidence for such a context-based modulation, and the Bayesian analysis of both experiments together revealed decisive evidence *against* it. If anything, both the single experiments and the Bayesian across-experiment analysis pointed to the opposite pattern: there was strong evidence for the signature pattern of positive and negative compatibility effects only when the athletes were presented *outside* their usual context (e.g., at the beach), but there was no such evidence when the athletes were seen *within* the contexts in which they usually carried out these behaviours (the tennis court, the soccer field). This counterintuitive pattern was even present in the original study on which the current work was based (Bach & Tipper, 2006), where the negative compatibility effects were numerically stronger for athletes' faces identified outside their usual contexts.

Together, while larger samples and/or stronger manipulations are required to establish whether the motoric modulation is indeed stronger for athletes outside their usual action contexts, the current data – and Bayesian analyses – provide clear evidence that it is *not* stronger when athletes are seen within their typical contexts. This result challenges the hypothesis that the compatibility effects emerge from sophisticated person-models which

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predict the actions an individual is most likely to carry out in a situation (e.g., Barresi & Moore, 1996; Bach & Schenke, 2017; Schenke, Wyer & Bach, 2017). Instead, the effects seem to reflect the re-activation of more stereotypical, not situation-specific action knowledge about the athletes that ultimately serves person identification rather than action prediction or social interaction. In such views, a kick is not predicted because it is the action we expect to see Ronaldo carry out on the soccer field, but simply because it has been a typical feature of this athlete in our prior perceptual experience with him, and can therefore help to confirm that it is really him that we are seeing.

The finding that such cross-checking occurs primarily when these athletes need to be identified outside their usual context fits well to such a view. It is well-established that other people – and objects in general – can be identified from minimal information when we see them in their typical situations that provide converging evidence for person identification (e.g., Davenport & Potter, 2004; Ganis & Kutas, 2003; Young, Hay, & Ellis, 1985). However, seeing them outside these contexts attracts attention and recruits more extensive knowledge about the stimulus to compensate for the increased uncertainty (e.g., Bar, 2003; Fenske, Aminoff, Gronau, & Bar, 2006; Reichardt, Polner, & Simor, 2020). If confirmed by further research, this would suggest that the observed 'mapping' of others' actions onto one's own motor system may not be a default process during social perception, but part of these compensatory activations of person knowledge, which is then actively projected onto the unusual stimulus to confirm – or reject – initial hypotheses about its identity. Note though that this would either require a stronger context manipulation and/or much larger sample sizes (n > 600 at the current effect size) to convincingly demonstrate such a stronger motoric modulation in the unusual Out-of-Context trials.

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Such an account would integrate the compatibility effects during person recognition with the larger field of person-knowledge, as noted above, but is also consistent with several other literatures that have argued that the activation of "embodied" knowledge reflects a process of confirmatory hypothesis testing. For example, Csibra (2007, see also Kilner, Friston & Frith, 2007[ab], Bach, Nicholson & Hudson, 2014) argued that the well-known motor activation during action observation does not reflect a bottom-up process of identifying the motoric components of the action, but a top-down verification about whether the observed action fits the goals we attribute to them. Consistent with such a proposal, these motor activations depend on observing a goal-directed action (e.g., Liepelt, Von Cramon, & Brass, 2008; Longo & Bertenthal, 2009; see Bach, Nicholson, & Hudson, 2014 for a review), and increase the less clear these goals are, consistent with such a secondary verification process (e.g., Nicholson, Roser, & Bach, 2017). Even more fundamental visuospatial perspective taking processes seem to be stronger with unusual contextual information, for example, when conflict between another's gaze and action need to be resolved (Furlanetto, Cavallo, Manera, Tversky, & Becchio, 2013) or the other person shows an unusual fearful facial expression, for which the referent in the real world is unclear (e.g., Zwickel and Müller, 2010). Butterfill and Apperly (2013) therefore argued for a two-stage approach to theory of mind, in which people can either be initially 'registered' but not fully represented (e.g., in terms of attitudes, beliefs, etc.), but which is expanded to more elaborate processing for more complicated or uncertain situations. The embodiment of the actions that others' typically carry out might therefore be part of such a secondary recruitment of knowledge that is engaged when the visual input is uncertain (e.g., when people need to be identified in unusual contexts).

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Conclusion

We tested whether effector-specific positive and negative compatibility effects when identifying well-known athletes emerge from person-models that predict this athlete's most likely forthcoming actions (kicking a soccer ball, hitting a tennis ball). We generally replicate these effects, showing that the typical actions of others are activated when they are seen, even when completely irrelevant to the participants' task. We cannot confirm, however, that these action expectations emerge from an integration of person and situation cues (e.g., Barresi & Moore, 1996; Bach & Schenke, 2017). Instead, our data suggests that person-specific motor knowledge is activated because it is a frequently encountered feature when watching these athletes. We argue that when these individuals are later re-encountered, such as in our task here, this information is used to confirm – in a perceptual hypothesis-testing process – one's initial hypotheses about the actor's identity, specifically in uncertain stimulus situations when the person is not encountered in their typical context.

Supplementary Material

The Supplementary Material is available at: qjep.sagepub.com

DOI: 10.1177/1747021820945270

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Figure Captions

Figure 1. Examples of the athlete stimuli, showing well-known tennis and soccer players either carrying out their typical actions (left two columns) or not carrying out these actions (right two columns), in either their usual contexts (top row) or outside these contexts (bottom row). Note that the stimulus images shown here are vectorized schematics but were presented as high-resolution photographs in the experiments.

Figure 2. Average response times for Experiment 1. The top panel shows average response times in the In-Context conditions, and the bottom panel shows average response times in the Out-of-Context condition. In each panel, the left bars reflect identification times of athletes carrying out their typical actions, and the right bars represent them not carrying out these actions. The black bars show identification with a congruent effector, and the white bars show identification with an incongruent effector. Error bars show the between-subjects standard error of the mean.

Figure 3. Trial sequence. A fixation point was presented for 800-100ms (randomly chosen), this was followed by a context priming image (either a beach scene or a tennis court/soccer pitch) presented for 500 ms. Finally, the image of the athlete was shown (either performing their typical action or not and either in their usual sporty context or not). Note that the stimulus images shown here are schematics but were presented as high-resolution photographs in the experiments.

Figure 4. Average response times for Experiment 2. The top panel shows average response times in the In-Context conditions, and the bottom panel shows average response times in the Out-of-Context condition. In each panel, the left bars reflect identification times of athletes carrying out their typical actions, and the right bars represent them not carrying out these actions. The black bars show identification with a Congruent effector, and the white bars show identification with an Incongruent effector. Error bars show the between-subjects standard error of the mean.

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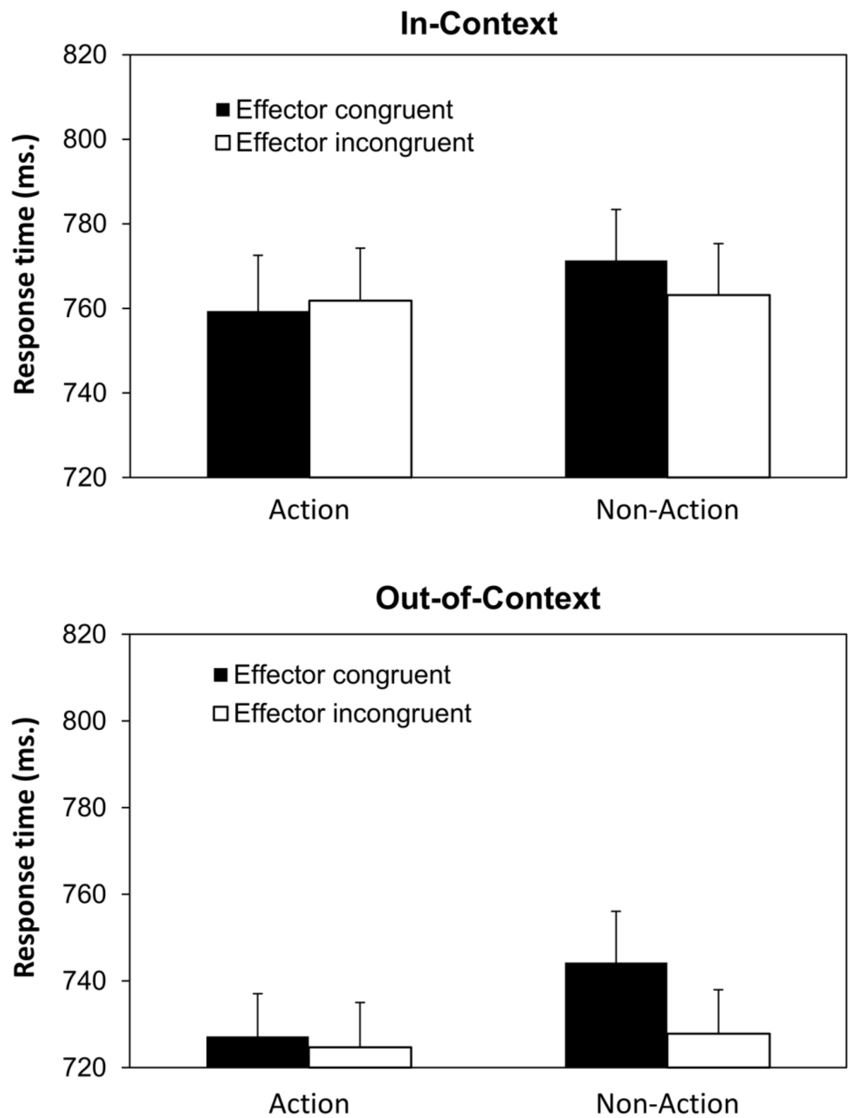
297x177mm (300 x 300 DPI)

DOI: 10.1177/1747021820945270



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148x190mm (300 x 300 DPI)

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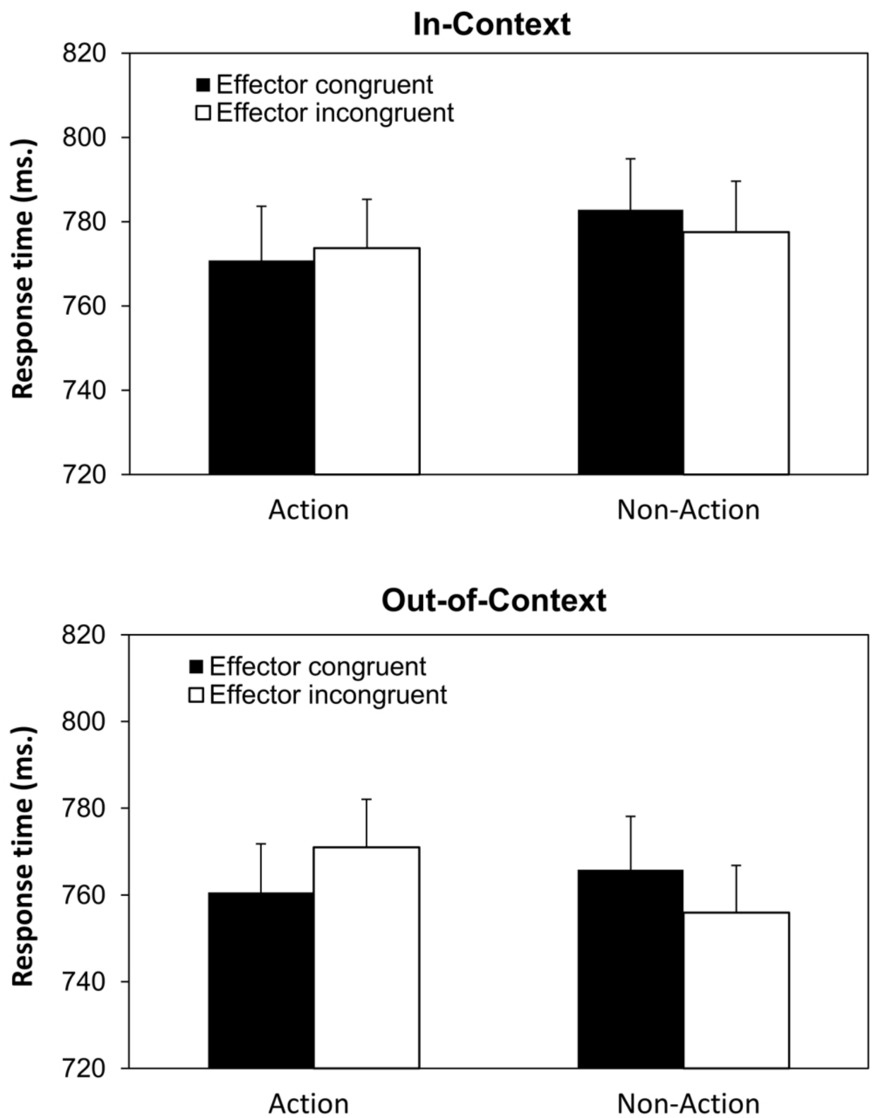
284x154mm (300 x 300 DPI)

DOI: 10.1177/1747021820945270



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152x190mm (300 x 300 DPI)

DOI: 10.1177/1747021820945270

Table 1. *Mean proportion of errors in Experiment 1. Values in brackets show standard deviations.*

	Action		Non-action	
	Effector Congruent	Effector Incongruent	Effector Congruent	Effector Incongruent
In-Context	.053 (.037)	.060 (.035)	.046 (.040)	.057 (.046)
Out-of-Context	.040 (.034)	.040 (.033)	.040 (.037)	.041 (.031)

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Table 2. *The mean proportion of errors in Experiment 2. Values in brackets show standard deviations.*

	Action		Non-action	
	Effector congruent	Effector incongruent	Effector congruent	Effector incongruent
In-Context	.046 (.036)	.047 (.032)	.038 (.035)	.038 (.035)
Out-of-Context	.034 (.030)	.034 (.031)	.030 (.028)	.040 (.035)

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