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

Kimberley C. Schenke[1], Natalie A. Wyer[2], Steven P. Tipper[3], Patric Bach[4]

[1] School of Natural and Social Sciences, University of Gloucestershire, Gloucestershire, UK

[2] Department of Psychology, East Anglia University, Norwich, UK

[3] Department of Psychology, University of York, Yorkshire, UK

[4] School of Psychology, Plymouth University, Devon, UK

* corresponding author kschenke1@glos.ac.uk

Tel: 01242 714559

School of Natural and Social Sciences

University of Gloucestershire

Cheltenham,

Gloucestershire,

GL50 4AZ

United Kingdom

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Abstract

We adapted an established paradigm (Bach & Tipper, 2007; Tipper & Bach, 2010) to test 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 with either hand or foot responses, while these athletes were seen either carrying out or not carrying out their typical actions, in contexts in which these actions are typically seen (soccer field, tennis court) or outside these contexts (beach, awards ceremony). Identifying not-acting athletes revealed the expected negative compatibility effects, such that viewing a tennis player led to faster responses with a foot than a hand, and vice versa for a soccer player. In line with the idea that these negative compatibility effects reflect the absence of a predicted action, these effects were eliminated (or turned into positive compatibility effects), when the athletes were seen carrying out their expected actions. Strikingly, however, these motoric biases were independent of the context in which the athletes were seen, and were, if anything, more robust in the out-of-context trials, even if the context was made salient (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 their perceptual representations, which are accessed when they 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 inherently ambiguous, and require one to rapidly make sense of the internal mental states that drive others' behaviour and respond to them appropriately. Motoric accounts of social perception argue that people solve this problem by mapping others' behaviour – in a simple bottom-up fashion – onto their 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 seen as a key mechanism in this mapping, directly matching incoming action kinematic information with the associated motor programs of 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 further 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; for examples of other actions, see Bach, Bayliss, & Tipper, 2011a; Stürmer, Aschersleben, & Prinz, 2000; for a review, see Cracco et al., 2018) and viewing another person perform an action 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 (Bach & Tipper, 2006; Bach, Peatfield, & Tipper, 2007).

More recently, it has 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 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. Recent approaches therefore cast social perception as a top-down process of hypothesis-testing, in which prior action expectations – derived from various contextual cues, such as facial expressions, nearby objects, or verbal statements – are constantly 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 models, the robust motor activation during action observation reflects not a bottom-up matching of observed behaviour to own motor representations, but instead the attempt to *predict* an action so that it can be matched to what was 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). In addition, there is evidence that motor activation during action observation anticipates forthcoming actions (Avenanti, Annella, Candidi, Urgesi, & Aglioti, 2013), that mirror neurons predictively code others' actions (Maranesi, Livi, Fogassi, Rizzolatti, & Bonini, 2014; Urgesi et al., 2010), that the motor activation associated with an observed action reflects its (inferred) goal rather than the actual motor behaviour (Liepelt et al., 2009), or that motor activations are strongest for actions appropriate for goal achievement (e.g., Bach, Bayliss & Tipper, 2011).

What is the source of these predictions? We and others have argued that next to the overt social cues – nearby objects, facial expressions or overt statements – investigated in most prior research (e.g., Bach, Nicholson & Hudson, 2014; Adams, Ambady, Macrae, & Kleck, 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), the *identity* of the actors themselves is an important contributor (Bach & Schenke, 2017; Barresi & Moore, 1996; Newen, 2015). It has been argued that 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; Monroy, Meyer, Gerson & Hunnius, 2017; Buchsbaum, Gopnik, Griffiths, & Shafto, 2011). As soon as such models are established, they provide information about which actions will be carried out when they are re-encountered in this situation. Consistent with such views, recent studies have shown, for example, that people's attention is automatically biased towards which object someone is expected to look at based on their past history (rather than where they are actually looking; Joyce, Schenke, Bayliss, & Bach, 2015), that people are faster in identifying 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 that people learn an individual's idiosyncratic "tells" to predict their actions in gambling (Heerey & Velani, 2010).

Here, we ask whether the activation of such internal person models can be tracked not only in perceptual measures, but in motoric activation as well, in line with the idea that one's motor system "emulates" or "predicts" the action we expect to see of the other person. Prior work from our lab and others (Bach and Tipper , 2006; Tipper & Bach, 2011; Candidi, Vicario, Abreu, & Aglioti, 2010; Sinnett, Hodges, Chua, & Kingstone, 2011) might have revealed just such an effect. Participants were asked to identify famous soccer and tennis players from their faces by making either hand or foot responses. The results revealed motoric effects consistent with a prediction of the movement that was not observed but *expected* of this athlete. Even when only the faces of the athletes were seen, and they were not engaged in an action, the main effector used in their sport (Ronaldo's foot, Federer's hand) influenced the participants' own foot and hand responses, such that participants were slower in using the body part that was primarily used in the athletes' sport (e.g., slower responses for hand than foot responses for tennis players, with the opposite observed for soccer players). In predictive processing views, these negative compatibility effects could index the activation of a predicted – but not yet perceived – action (i.e., a kick for Ronaldo). Indeed, the effects turned into the usual positive compatibility effects, when, in a later study, the same athletes were seen carrying out their expected actions (hitting a tennis ball or kicking a football; Tipper & Bach, 2011).

Here, we replicate these effects and test whether they index the activation of a person-specific internal model for action prediction. One key signature of such person-models is that they should not capture just which actions others' typically carry out, but also in which situations these actions are typically seen in (Bach & Schenke, 2017; Barresi & Moore, 1996). In other words, participants should not predict that Ronaldo generally kicks a ball, but that he would do so specifically when he is seen on the soccer pitch. Similarly, a famous tennis player should only be predicted to use the racket on, but not off, the tennis court. This situation-specificity hypothesis therefore predicts that both negative compatibility effects (when athletes are not carrying out the expected actions) and positive compatibility effects (when they are acting as expected) are observed primarily when the athletes are observed in their sporty contexts (i.e., on the soccer pitch or tennis court, wearing the associated attire), but less so in neutral contexts where there is no specific expectation to see the athletes carry out their sporty actions (e.g., at the beach, at an awards ceremony).

We conducted two experiments in which, similarly to Tipper and Bach (2010), we presented participants with various images of four famous athletes – two tennis players and two soccer players – either carrying out their usual actions (kicking a football, hitting a tennis ball with a racket) or showing them in a neutral pose not related to these typical behaviours (see Figure 1 for examples). In addition, we now also varied independently whether the athletes were seen within their typical contexts (e.g., on the tennis court or soccer pitch) or outside these contexts (e.g., at an awards ceremony or at the beach). Participants had to identify these athletes using either a keyboard or a foot pedal, 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 test, first, whether the athletes' typical actions are embodied within the observer such that athletes are identified more quickly when using the effector associated with their sport when seen acting, and vice versa when not acting, thereby replicating the face inhibition effect (Bach & Tipper, 2006; Tipper & Bach, 2010). Second, it allows us to test whether these effects are indeed stronger when the actors are seen in their typical contexts, as predicted from the hypothesis that these effects reflect (failed) motor predictions of the athletes' expected actions in the given situation.

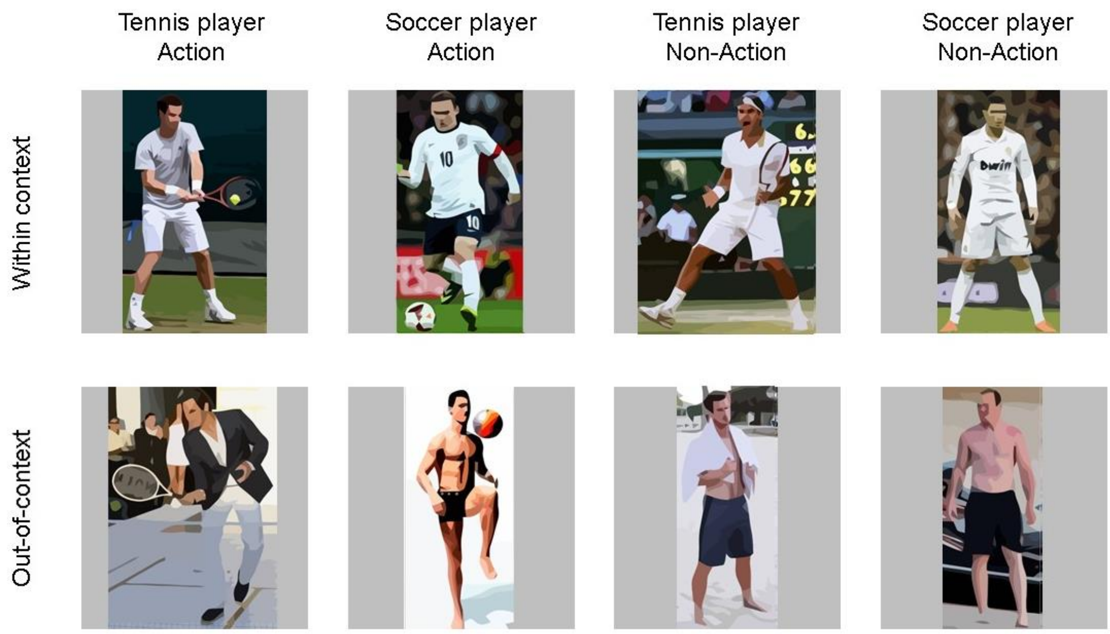

Figure 1. Examples of the athlete stimuli, showing well-known tennis and soccer players either carrying out their typical actions (left two columns) or not carrying out these actions (right two columns), in either their usual contexts (top row) or outside these contexts (bottom row). Note that that the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

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 players (Andy Murray, Roger Federer) either acting, or not acting, in a neutral context 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, 2010). 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 females, 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. Sample size was based on prior studies on this effect (Bach & Tipper, 2006; Tipper & Bach, 2011; Sinnett et al., 2011). It provides 80% power to detect effect sizes of $d > .385$. Four participants had technical difficulties with the foot pedal and were excluded from the analysis. All experiments were 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], and we report all measures, manipulations and exclusions for both experiments. All participants provided written consent.

Materials and apparatus

The experiment was administered with E-prime 2.0 (Psychology Software Tools, Pittsburgh, PA). 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 athlete was shown in two photographs for each of the four conditions (acting in-context, not acting in-context, acting out-of-context, not acting out-of-context). The out-of-context images showed the athletes in any situation other than a tennis court or soccer field, such as at an awards ceremony, on the beach, etc.

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, this will not be discussed further.

Procedure

Each trial consisted of 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 footballer and one tennis player had to be identified by pressing the foot pedal, and the second footballer and tennis player had to be identified by pressing a key on the keyboard (counterbalanced across 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. There were 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.

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 for each participant were averaged by condition 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 athlete's typical effector, incongruent with 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. We also predicted a three-way interaction of Context, Action and Effector Congruency – specifically, we expected compatibility effects to be larger when the athletes are seen in their usual contexts. 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 $p <.01$.

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 effect 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, there were no statistically robust differences between congruent and incongruent responses for the action trials, $F[1,35] =1.251$, $p =.306$. 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 within-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, $F[1,35] = 1.111$, $p = .299$, $\eta\rho^2 = .031$.

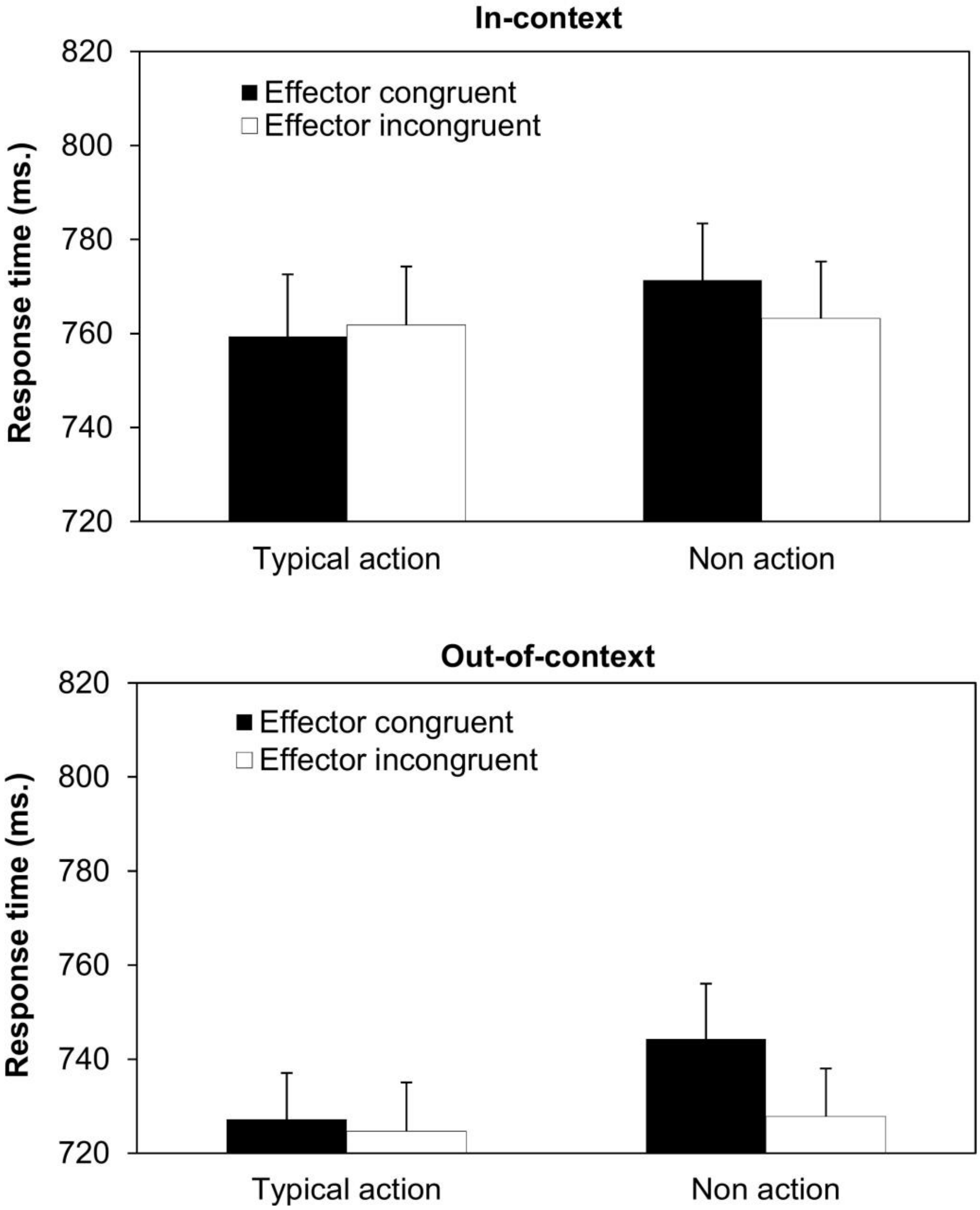

Figure 2. Average response times for Experiment 1. The top panel shows average response times in the in-context conditions, and the bottom panel shows average response times in the out-of-context condition. In each panel, the left bars reflect identification times of athletes carrying out their typical 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 standard error of the mean.

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.

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)

Correlations with subjective ratings

In the study of Tipper and Bach (2010), 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. 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 motor expectation effects are dependent on whether the athletes are seen acting or not-acting, and whether they are seen within or outside their usual sporting contexts. The results replicated 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 our predictions, Experiment 1 did not provide evidence that these 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, effects were more reliably observed when the athletes were seen in neutral contexts. One reason for the absence of such a difference might be that the effect size is too small to be detectable within the current paradigm. The relevant context may not have been not 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 seen in.

Experiment 2

Experiment 2 sought to enhance the availability of context information. 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) 500 ms. prior to the critical athlete photograph. As before, the following photograph then showed one of the four athletes either carry out their specific action (kicking or playing tennis) or not acting in an unusual situation or in their sporty context shown in the context preview image. Participants, again, identified the athletes with a foot or hand response which was either congruent or incongruent with the expected or observed action of the athlete.

We, again, 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 an atypical situation (e.g., at the beach), where such an action expectation is reduced. Thus, as before, the within-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, 2010). These effects should be absent or reduced when the athletes are seen outside their usual contexts.

Method

Participants

56 participants (35 females, mean age = 21.29 years, SD = 5.28; 49 right-handed) took part in the study in exchange for course credit. Sample size was determined with G-Power

(Erdfelder, Faul, Lang, & Buchner, 2007) based on the effect size (*d* = .80) for the Action by Effector Congruency interaction observed in Experiment 1, which indicated that a sample size of at least 50 was required to reliably detect the interaction between Action and Effector Congruency with .80 power.

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/football scene was now presented for 500 ms prior to the critical photograph. Moreover, all out-of-context photographs now showed the actors on the beach to reduce possible confounds in the previous stimuli whereby the out-of-context photographs could show the athletes in several situations (e.g., at an awards ceremony, in the street, or on the beach) while the sporty scenes always showed the same environment (tennis court, soccer stadium).

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/football pitch) presented for 500ms. Finally, the image of the athlete was shown (either performing their typical action or not and either in context or not). Note that that the stimulus images shown here are schematics but were presented as high-resolution photos in the experiments.

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 athlete's typical effector, incongruent with 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 $p < .01$.

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 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 our predictions, when out-of-context and within-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 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, $F[1,52] = .244$, $p = .624$, $\eta\rho^2 = .005$.

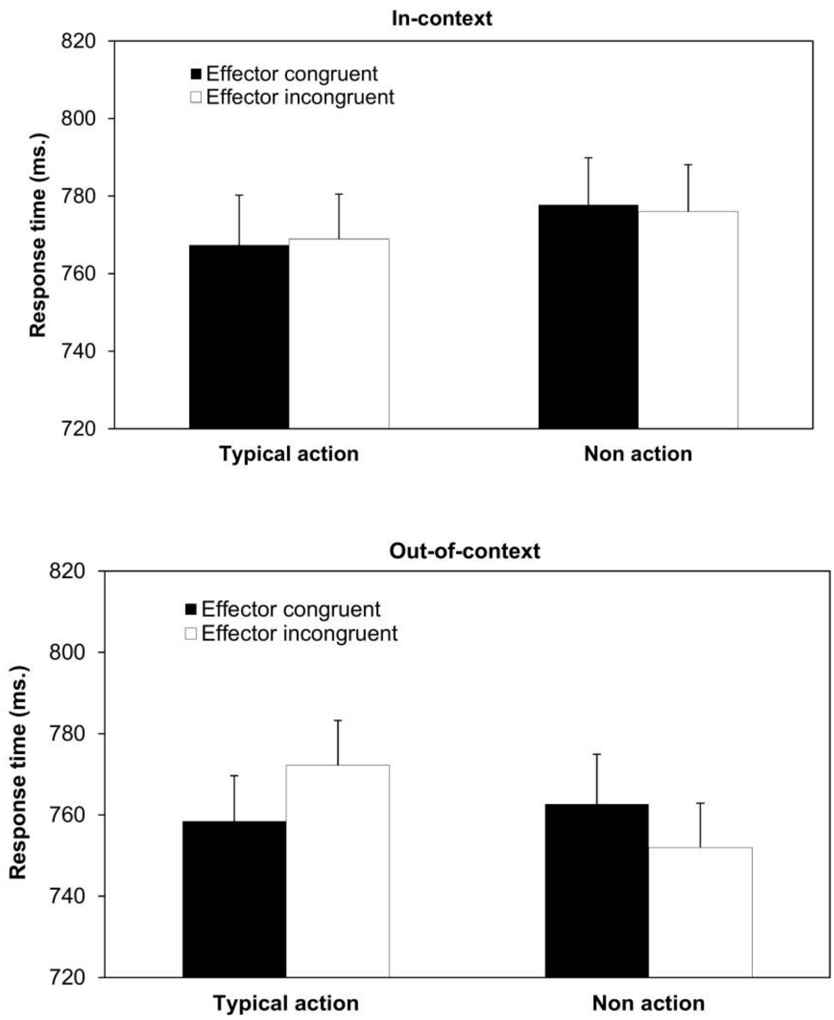

Figure 4. Average response times for Experiment 2. The top panel shows average response times in the in-context conditions, and the bottom panel shows average response times in the out-of-context condition. In each panel, the left bars reflect identification times of athletes carrying out their typical 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 standard error of the mean.

Error rates

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

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)

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 & Tipper, 2006) and Experiment 1. Accordingly, 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 study.

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 they 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. 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 reliably observed 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 across both experiments.

Across-experiment analysis

Both experiments provided evidence that seeing famous athletes act or not act modulates the observer's motor system in opposite directions. However, neither of the two experiments supported the prediction that the positive and negative compatibility effects were larger when the athletes were presented in their usual contexts (e.g., tennis court, soccer field) than out of these contexts (e.g., at the beach). If anything, effects seemed to be more robust when athletes were seen outside their usual contexts. In order to estimate to what extent the combined data provide evidence for – or against – a difference between the two context conditions, we conducted an exploratory analysis (using both frequentist and Bayesian analysis methods) combining the data from both experiments to provide additional power.

This analysis also allows us to address another question. 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 when the athletes were seen not acting were statistically robust in Experiment 1, they were only present numerically in Experiment 2. Conversely, the positive compatibility effects when the athletes were seen executing their actions 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 both type of effect.

We used the same ANOVA model as in the previous experiments and applied it to their 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 factor 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, showing that viewing acting or non-acting athletes induces congruency effects in opposite directions, $F[1,87] = 10.66$, $p = .002$, $\eta\rho^2 = .109$, $BF_{10} = 3.954$. Moreover, 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, $BF_{10} = .251$. Nevertheless, 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 small to considerable evidence for its *absence* in the within-context trials, $F[1,87] = 2.448$, $p = .121$, $\eta\rho^2 < .001$, $BF_{10} = 0.367$. Step-down analyses for each type of action separately showed that this interaction is mainly driven by the negative compatibility effects induced by 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 induced by seeing them act, $F[1,87] = 0.485$, $p = .488$, $\eta\rho^2 < .006$, BF10 = 0.220.

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 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 the seen individuals typically carry out. 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 not acting. Participants identified these individuals by making responses with their own hands or feet, allowing us to test whether merely identifying tennis and soccer players biases the observer's motor system towards the effector typically used in their sport, even if this action is not currently observed.

Both experiments replicated previous findings that identifying famous athletes whilst seeing them either act or not-act modulates the observers' motor systems (Bach & Tipper, 2006; Tipper & Bach, 2011; Candidi et al., 2010; Sinnett et al., 2011). Most importantly, when the athletes were seen *not carrying out these 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 in prior work by us (Tipper and Bach; 2011; Bach & Tipper, 2006) and others (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., Ronaldo). We also replicate – 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 analysis of 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 shown 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 upon person-models that include not only information about these 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 typical behaviour (Schenke et al., 2016; Joyce et al, 2015; for theoretical arguments, see Bach & Schenke, 2017; Barressi & Moore, 1996). These actions are derived spontaneously when these athletes are seen and modulate the observer's motor system, such that prediction failures – seeing an athlete *not* carry out their expected action – impairs the use of the relevant body part in the observer (Bach et al., 2006).

Strikingly, this modulation of the motor system was independent of the context in which the athlete was presented. 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 modulation. If anything, in both experiments, the signature pattern of positive and negative compatibility effects upon seeing the athletes was more robust, or only observed, when the individuals were presented *outside* their usual context (e.g., at the beach), that is, in situations in which these actions would be less likely. Indeed, Bayesian analysis of the combined data of both experiments revealed considerable to strong evidence for the presence of such a modulation in the out-of-context trials, but evidence for the *absence* of such effects in the in-context trials. This counterintuitive pattern was also 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.

These results are not consistent with our original hypothesis that the compatibility effects emerge from sophisticated person-models which predict the actions an individual is most likely to carry out in different situations (e.g., Barresi & Moore, 1996; Bach & Schenke, 2017; Schenke, Wyer & Bach, 2017). Instead, the effects seem to reflect more stereotypical, not situation-specific knowledge about the athletes – that Ronaldo typically uses his foot and Roger Federer his hand – which is activated when they are seen again. This does not argue against a predictive processing account in general. However, it does suggest that the system does not predict a kick because that is the action we expect to see Ronaldo carry out on the soccer field, but simply because this action has been a typical feature of this athlete in our prior perceptual experience with him, and can therefore help to confirm if it is really him that we are seeing.

The finding that such cross-checking occurs primarily when these athletes needed 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 (e.g., Davenport & Potter, 2004; Ganis & Kutas, 2003; Young, Hay, & Ellis, 1985). However, in cases where the out-of-context situations do not provide converging and supporting evidence for person identification processes, recognition processes may draw upon more extensive knowledge about the person to compensate for the increased uncertainty (e.g., Bar, 2003; Fenske, Aminoff, Gronau, & Bar, 2006). If confirmed by further research, this would suggest that 'mapping' actions onto one's own motor system may similarly not be a default process during social perception, but part of these compensatory activations of associated person knowledge, which is then actively projected onto the unusual stimulus to confirm – or reject – initial hypotheses about its identity.

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 such 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).

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's, 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

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