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Title

Action preferences and the anticipation of action outcomes

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Abstract

Skilled performers of time-constrained motor actions acquire information about the *action preferences* of opponents in an effort to better anticipate the outcome of that opponent's actions. However, there is reason to doubt that knowledge of an opponent's action preferences would unequivocally influence anticipatory responses in a positive way. It is possible that overt information about an opponent's actions could distract skilled performers from using the advance kinematic information they would usually rely on to anticipate actions, particularly when the opponent performs an 'unexpected' action that is not in accordance with his or her previous behaviour. The aim of this study was to examine how the ability to anticipate the outcome of an opponent's actions can be influenced by exposure to the action preferences of that opponent. Two groups of skilled handball goalkeepers anticipated the direction of penalty throws performed by opponents before and after a training intervention that provided situational probability information in the form of action preferences (AP). During the training phase participants in an *AP-training* group anticipated the action outcomes of two throwers who had a strong preference to throw in one particular direction, while participants in a *NP-training* group viewed players who threw equally to all directions. Exposure to opponents who did have an action preference during the training phase resulted in improved anticipatory performance if the opponent continued to bias their throws towards their preferred direction, but decreased performance if the opponent did not. These findings highlight that skilled observers use information about action preferences to enhance their anticipatory ability, but that doing so can be disadvantageous when the outcomes are no longer consistent with their generated expectations.

Keywords: anticipation; motor actions; situational probability; performance analysis; penalty; handball.

PsycINFO codes: 2323; 2330; 3720

1. Introduction

The 2006 FIFA World Cup quarter-final between Germany and Argentina was an exciting game whose result, like many other football matches, was decided by a penalty shootout. Intriguingly, observers around the world watched on as the German goalkeeper, Jens Lehmann, prepared for the shootout by taking a small piece of paper from inside his sock that showed him where the Argentinian players typically directed their kicks in penalty situations. By doing so, Lehmann was attempting to enhance his likelihood of success by using supplementary information about the individual action preferences of his opponents. Lehmann's awareness of the kicking preferences of his opponents appeared to help him, as Germany went on to win the penalty shoot-out by five goals to three as a result of Lehmann successfully saving two penalties from his Argentinian opponents. Consequently, the story about the small piece of paper Jens Lehmann kept inside his sock has become a legendary fable in footballing folklore, and this and other similar stories have most likely played a role in the proliferative use of probabilistic information in professional (and semi-professional) sport. However, while it might seem intuitive to think that knowledge about an opponents' action preferences should help in these types of scenarios, it is possible that Lehmann's success came about in spite of – rather than as a result of – his knowledge of the action preferences of his opponents. The very explicit information about the action preferences of an opponent could encourage skilled performers to adopt strategies that are less reliable than the ones they would typically use. In essence, by expecting one particular action outcome to occur, the skilled performer may be less likely to use the information that they have consistently relied on throughout their development to anticipate the outcome of their opponents' actions.

The ability to anticipate the actions of others is an important skill that supports the way humans interact. Movement-specific (kinematic) information can provide useful insights into a person's identity, mood, intention, and crucially, about the likely outcome of their movement (Blake & Shiffrar, 2007). For instance, skilled athletes across a broad range of different sports are better than novices at predicting the outcome of their opponents' actions (Abernethy & Russell, 1987; Jones & Miles, 1978). As a case in point, skilled soccer goalkeepers (like Jens Lehmann) are able to anticipate the likely outcome of an opponent's penalty kick even before the moment the ball is kicked. They do so by observing the

movements of the kicker's hips, supporting (non-kicking) leg, and kicking leg to provide clues about where the ball is likely to be directed (Savelsbergh, van der Kamp, Williams, & Ward, 2005; Savelsbergh, Williams, van der Kamp, & Ward, 2002). Skilled athletes develop the ability to pick-up this advance kinematic information by virtue of experience, particularly when the temporal demands of the task become excessive (Weissensteiner, Abernethy, Farrow, & Müller, 2008). This information allows skilled performers to account for the tight time-constraints inherent in many sporting tasks by reacting earlier (Shim, Carlton, Chow, & Chae, 2005) and/or by facilitating their performance to ensure they arrive in time to intercept their target (Dicks, Davids, & Button, 2010).

While it is well established that action outcomes can be anticipated on the basis of kinematic information, more recent research has shown that non-kinematic information can also be used to facilitate the anticipation of action outcomes. Abernethy et al. (2001) demonstrated that *situational probability* information could be used to anticipate action outcomes based on the particular context in which the action was performed. In their study, expert and less-skilled squash players took part in simulated on-court match play while wearing liquid-crystal goggles that allowed their vision to be occluded at different moments during their opponent's stroke. Following visual occlusion, participants were required to continue to complete their response (by playing a return shot). Not surprisingly, if occlusion took place during the hitting action of the opponent, the expert players could better anticipate the direction to move in to play an appropriate response. More interestingly though, the expert players were also better able to anticipate the best direction to move in when occlusion took place *before* their opponent commenced their hitting action. That is to say, they were able to respond even when kinematic information about the opponent's shot was absent. Evidently, the skilled players were using their opponent's *position on the court* to predict the likely direction of the opponent's shot. This result demonstrates that skilled performers use contextually-specific information – in this case the court position of the opponent – to guide their anticipatory responses (see also Loffing & Hagemann, 2014). Crucially, this result raised the possibility that next to the pick-up of advance kinematic information, expert performers could also use a variety of probabilistic information to aid in their anticipation of action outcomes (see also Buckolz, Prapavesis, & Fairs, 1988; Paull & Glencross, 1997, and relatedly, for how information about a priori information, 'priors', can

influence motor behaviour, see Berniker, Voss, & Körding, 2010; Körding & Wolpert, 2004; Narain, van Beers, Smeets, & Brenner, 2013).

Despite the pioneering contribution of the Abernethy et al. study, surprisingly few studies have since sought to examine the influence of probabilistic information on anticipatory performance. One exception is a recent study by Farrow and Reid (2012) who assessed the ability of junior tennis players to anticipate movement outcomes, in their case tennis serves, based on the game score when playing a specific opponent in a simulated match situation. Skilled junior players predicted the direction of tennis serves viewed on a television screen from the perspective of a receiving player, with serves shown as a series of games and sets, and the match-score shown prior to each serve. Critically, and unbeknown to the participants, the first serve in each game was always hit in the same direction. The analysis of participant response times found that a group of experienced junior players were able to detect and use this pattern to expedite their anticipation of subsequent serves. These results show that additional information about situational probabilities, in this case the game score, can help to enhance the speed with which skilled players react to actions. Further, it highlights that the ability to anticipate action outcomes on the basis of situational information appears to encapsulate information that is available both independently of, and specific to, the opponent producing the action. While Abernethy et al.'s study points to the use of generic information (in that case court position) that is most likely to be available irrespective of the particular habits of the opponent, Farrow and Reid show that player-specific information (in that case the shot played by the opponent on a particular point) can also aid anticipatory performance.

Together, these studies provide examples where information about situational probabilities can be used based on particular contextual information (such as the court position of an opponent or the game score); however, similar types of probabilistic information can also be available even when most of this contextual information is absent. Individual performers can have a bias in the type of action they perform in any given scenario, even though there might normally be no specific advantage when performing that given action. For instance, there should be no specific advantage in aiming a penalty kick towards any particular corner of a goal if both the kicker and the goalkeeper are standing in line with the centre of the goal. However, actors can still possess their own individual *action preferences* in these

situations, that is, there can be a bias in the relative distribution of their preferred actions. These action preferences may arise as a result of the actor's greater proficiency in executing one particular motor action over others, and/or simply because of their previous success when performing that action. Athletes tend to learn about the action preferences of their opponents, though historically athletes have been left to search for and identify these biases in their opponents' actions themselves. However, many professional sporting organisations now employ performance analysts to watch games and document probabilistic information on behalf of the players and coaches (e.g., Hughes & Bartlett, 2002). The example of Germany in the World Cup quarter-final highlights this, with players actively using information about action preferences in an effort to enhance their anticipatory ability. This raises the question of whether doing so is likely to provide an advantage – or a disadvantage – to the person attempting to anticipate the action outcomes of their opponent.

It seems reasonable to expect that knowledge of an opponent's action preferences should help to facilitate success when seeking to anticipate the outcome of their actions. Intuitively, learning that an opponent is more likely to perform one action over any other should lead to a better response; in essence, the observer will be expecting a particular outcome and should, as a result, be better prepared to respond to it. For instance, Navia et al. (2013) have shown that when soccer goalkeepers are told that an opponent will direct a higher proportion of kicks in one direction, this knowledge of action preferences facilitates performance by improving both response time and response accuracy (see also Barton, Jackson, & Bishop, 2013). However, there are two key issues to consider that suggest this might not necessarily always be the case. First, it is entirely possible that explicit guidance about the likely outcome of an action could well be a disadvantage as it could distract skilled performers from making the types of well-learned responses that they are accustomed to enacting. Skilled performers develop their expertise by using advance kinematic information to guide their motor responses (Shim, et al., 2005), and they are thought to do so without necessarily having explicit knowledge of how or why the response was performed (Farrow & Abernethy, 2002; Jackson, Warren, & Abernethy, 2006; Mann, Abernethy, & Farrow, 2010). Therefore, by drawing attention towards particular outcomes or sources of information, additional information about the likely outcome may distract skilled performers from

picking-up on the kinematic patterns they would usually rely on to anticipate action outcomes. The second key issue to consider is that, while knowledge of action preferences may provide some form of advantage when the opponent acts in accordance with their existing preferences, it may be a distinct *disadvantage* if there is incongruence between the expected and actual actions performed by the opponent (e.g., Gray, 2002a, 2002b). If the expected outcome (based on information about action preferences) matches the performed action, and hence also the advance kinematic information, then it seems plausible that the knowledge of the action preference should facilitate an advantage that is above and beyond that possible when relying on kinematic information alone. In contrast, if the expected outcome is in conflict with the advance kinematic information then it seems reasonable to expect that the information about action preferences may harm rather than support anticipatory performance.

The aim of this study is to examine how the ability to anticipate the outcome of an opponent's actions can be influenced by exposure to the action preferences of that opponent. In particular, we were interested in how action preferences would influence the ability of an observer to anticipate the actions of an opponent who did, and did not, continue to act in accordance with their previous action preferences. Two groups of skilled handball goalkeepers anticipated the direction of penalty throws performed by opponents both before and after a training intervention that provided situational probability information in the form of action preferences. During the training phase, participants were allocated to one of two groups: a group who anticipated the action outcomes of two throwers who had a strong preference to throw in one particular direction, and a group who viewed players who threw without a preference in any particular direction. We hypothesised that knowledge of action preferences would influence the ability of observers to anticipate action outcomes when compared to those who trained without an action preference. More importantly, we hypothesised that exposure to throwers with an action preference during the training phase would provide a clear advantage when anticipating the action outcome of an opponent who did continue to throw in that preferred direction in the post-test, but would be a distinct *disadvantage* if the opponent no longer continued to throw in their preferred direction in the post-test.

2. Method

2.1. Participants

A total of 20 female participants (M_{age} = 22.3 years; *SD* = 3.3) took part in the study. All were skilled handball players competing as goalkeepers in any of the first three divisions of the National Womens Handball League in the Netherlands. Participants had an average of 12.3 years of playing experience (*SD* = 3.5), and at the time of testing averaged 9.1 hours of practice per week including 1.4 hours of goalkeeper-specific training. The local institutional ethics committee approved the experimental procedure and all participants signed an informed consent form prior to participating in the study.

2.2. Apparatus and Stimuli

Two skilled female handball players (M_{age} = 23.5 years, *SD* = .71) were filmed while taking penalty shots at goal to produce video stimuli for use in the experiment. Both players were right-handed throwers and competed in the highest division of the National Handball League at the time of recording. A digital video camera (Canon 3CCD Digital Video Camcorder XM2; 25 Hz, shutter speed 1/500 s) was placed in the centre of a standard sized handball goal facing towards the centre of the 7m penalty-line. The camera was positioned 1.7m above the ground to simulate the viewpoint of a goalkeeper attempting to save penalty shots at goal.

The two throwers were each required to stand at the 7m penalty-line and to throw the ball towards one of the four corners of the goal. Tape was used to make 60x60cm squares (not visible to the camera) in each of the four corners of the goal, and only those throws where the ball passed through these squares were included as experimental stimuli. An experimenter encouraged the thrower to act as they would in a match situation, in particular, to try not to provide the observer with any information about the corner they were aiming towards. The experimenter then on each trial instructed the thrower which of the four corners they should direct their throw towards. A minimum of 90 successful throws were recorded for each of the two throwers.

Each video clip was edited to produce an *unoccluded* and an *occluded* version of the clip (Adobe Premiere Elements 7.0). In the unoccluded clips the entire throwing action and ensuing ball-flight was shown. In the occluded version, vision was completely occluded two frames before the ball left the thrower's hand. Pilot testing on skilled handball players

(different to those recruited for the experiment proper) demonstrated that this moment of occlusion ensured that participants could predict the corner that the throw was directed towards at a level that was above that achievable by guessing, but below a ceiling level of performance.

2.3. Procedure

Participants were randomly allocated to one of two different groups that differed according to their training intervention: an action-preference group (*AP-training* group) or a no action-preference group (*NP-training* group). During the training intervention, participants in the AP-training group anticipated the action outcomes of two players who did have an action preference, specifically, 75% of all throws were directed towards one particular corner of the goal. In contrast, participants in the NP-training group viewed players who did not have an action preference, that is, the throws were equally likely to be thrown to each of the four corners of the goal. Testing for each participant took part in three successive phases: (i) a pre-test, (ii) a training intervention, and (iii) a post-test.

Pre-test. A total of 48 video clips (24 clips for each of the two throwers) were used for the pre-test. The test was designed so that, for all participants, one of the two throwers had an action preference and the other thrower did not. For the player with the action preference, 75% of all clips for that thrower displayed throws that were directed towards one particular corner (always the top-left corner) while the remaining 25% of clips were evenly distributed between the remaining three corners. For the player without the action preference, the 24 throws were evenly distributed between the four corners of the goal. The clips for each thrower were blocked together (and presented in a different randomised order for each participant) to provide a greater chance that any differences observed between the throwers was the result of action preferences. The order of presentation of the thrower with and without the action preference was counterbalanced across participants. Importantly, the thrower with the action preference was also counterbalanced across participants and groups to ensure that any kinematic differences between the two throwers did not confound any conclusions to be made based on the presence and/or absence of an action preference.

E-prime software (Psychology Software Tools, Inc., Pennsylvania, USA) was used to control the presentation of clips in the pre-test. Participants were required to press and hold down

with their index finger the centre key on a numerical keypad (number '5') to commence each trial. Upon commencement of the trial participants viewed the occluded version of the clip. Participants were instructed to predict which of the four corners of goal the throw was directed towards and to move their finger from the centre key to a corresponding key on the numerical keypad (by pressing '1', '3', '7', or '9' for bottom-left, bottom-right, top-left, and top-right respectively from the goalkeeper's perspective). Participants were asked to respond as quickly and as accurately as possible and were given a maximum of 3s to make their response otherwise the trial was excluded from all analyses. The video screen turned black at the conclusion of the video clip or as soon as the computer registered the participants' response (whichever occurred earlier). Eight practice trials were completed (one to each corner from each thrower; all clips unique to those seen during testing and training) prior to commencing the pre-test. Participants received feedback about their performance during the practice trials but not in the pre-test proper.

Training Intervention. Participants viewed a total of 72 video clips (36 clips for each of the two throwers) during the training intervention. Different sets of training stimuli were prepared for the two intervention groups. In the clips prepared for the AP-training group, 75% of clips for each thrower showed throws directed towards the top-left corner of goal, while the outcome of the remaining 25% of clips were evenly distributed across the remaining three corners. In the clips prepared for the NP-training group, the outcomes of the trials for both throwers were evenly distributed across the four corners of goal. All of the clips for each thrower were blocked together (following the same randomised order for all participants in each group), with the order of presentation of the two throwers counterbalanced across participants. All clips employed as training stimuli were different to those used in the pre- and post-tests.

Windows Media Player (Microsoft, Washington, USA) was used to present the clips shown in the training intervention. During the training phase, participants first viewed the occluded version of the clip and were given 5s to allow sufficient time for them to mark on a piece of paper the corner corresponding to the direction that they anticipated the throw was directed towards. Following this the unoccluded version of the clip was shown to provide feedback about the actual outcome of the throw.

Post-test. Participants completed a post-test immediately after the training intervention. The post-test was identical to the pre-test with the exception that the video clips were shown in a different randomised order. As a result, the overall experimental design allowed for a comparison of four possible experimental conditions (see Table 1): AP in test and training, AP in training but not in test, AP in test but not in training, and no AP in test or training.

Please insert Table 1 about here

Following the post-test, participants completed an exit questionnaire designed to establish whether they had recognised any action preferences. In particular, participants were asked for each thrower whether that player had a preferred throwing direction during testing and in the training intervention. If they answered yes, they were asked to nominate that thrower's preferred direction.

All testing was performed on a 17-inch laptop (Acer Aspire 5750) with a viewing distance of approximately 50cm. At no point were any explicit instructions provided to participants about the action preference of either player seen in the video clips. All testing took place in one session with the entire experiment taking each participant approximately 35 minutes to complete.

2.4. Data analysis

The mean *response accuracy* (RA) was the key measure of performance for our task and was calculated for each thrower by determining the percentage of trials where the participant correctly anticipated the outcome of that opponent's throws. We also calculated the mean *response time* (RT) for each thrower to ensure that changes in RA were not simply a trade-off with response time by determining the mean time elapsed between the conclusion of the video clip and the registration of the participant's key-press response.

Because of the potential for speed-accuracy trade-offs between pre- and post-tests in tests of anticipation, we checked the mean ΔRT for each participant to ensure that there was consistency across participants in the change in RT from pre- to post-test. Initial inspection

of the results suggested that participants generally did not change their RT from pre- to post-test (mean ΔRT = 9.6 ms, 95% CI = -103 to 122.6 ms). However, a box-plot analysis revealed one significant outlier (in the group that trained with the AP) who increased their RT 671.5 ms from pre- to post-test, most likely due to an excessively fast RT in the pre-test. Accordingly, the results for this participant were excluded from all analyses (mean ΔRT after exclusion of outlier = -25.3 ms, 95% CI = -110 to 60 ms; RT in pre-test [M ± SD] = 813 ± 277 ms, RT in pre-test [M ± SD] = 788 ± 293 ms). No outliers were identified in the analysis of ΔRA and the remaining data for ΔRA and ΔRT satisfied the assumption of normality.

A preliminary check of pre-test response accuracy was performed to ensure that there were no floor or ceiling effects in pre-test performance that would hinder the ability to test for a potential decrease or improvement in performance respectively. Specifically, separate planned one-sample t-tests demonstrated that participants in each of the two training group anticipated the direction of the throws at both a level comfortably above 25% (the level achievable by chance), and also less than 100% (reflecting perfect performance), irrespective of whether the thrower did or did not have a preferred throwing direction (Mean RAs for the AP-training group = 50.6 & 58.9% and for the NP-training group = 52.5 & 54.8% for player with and without-AP respectively; all one-tailed *p*s < .005, *Cohen's d* = 1.12-4.85). This result ensured that there were no potential floor effects when seeking to examine for decreases in performance following the training intervention, and equally, that there were no ceiling effects when seeking to find potential improvements in performance. Importantly, a 2 (AP-in-test) x 2 (training group) ANOVA on pre-test RA also confirmed that there were no differences between the different AP-in-test conditions or training groups (main effects *p*s > .37, interaction *p*=.62).

The key dependent variable of interest (RA) was subject to a 2 (AP-in-test: thrower with AP, thrower without AP) x 2 (test occasion: pre-test, post-test) x 2 (training group: AP-training group, NP-training group) ANOVA with repeated measures on the first two factors to assess whether any changes in anticipatory performance from pre- to post-test were influenced by the presence of an action preference in the training intervention. In the case of significant changes in response accuracy, we performed an additional 2 (AP-in-test) x2 (test occasion) x 2 (training group) ANOVA on the RT data to check whether any changes in response accuracy were simply a by-product of a trade-off with response time. The effect size for

ANOVA testing is reported as partial eta squared (η_p^2) and for t-tests is reported as Cohen's *d*. There were no violations of the sphericity assumption, and alpha was set at .05 for all testing.

3. Results

3.1. Manipulation checks

The results of the exit questionnaire showed that participants in the group who trained with an AP almost always correctly identified a bias in the direction of the throws during the training phase. Nine out of ten participants in the AP-training group correctly identified that both opponents had a bias to throw towards the top-left corner during the training phase. One participant reported an incorrect direction for just one of the two opponents. Importantly though, the change in response accuracy from pre- to post-test for this participant was not significantly different to the remainder of the participants who trained with an action preference, and so her data were kept in the overall analysis. Interestingly, seven of the ten participants in the NP-training group thought that both throwers *did* have a bias to throw towards one particular direction during the training phase even though no such bias was present.

The training intervention resulted in significant changes in the likelihood that participants predicted more throws were directed towards the biased direction (top-left). A 2 x 2 x 2 ANOVA performed on the percentage of trials where participants responded 'top-left' revealed a significant 2-way interaction between test occasion and training group, $F(1,17) = 6.67$, $p = .019$, $\eta_p^2 = .28$, with the 3-way interaction (AP-in-test x test occasion x training group) approaching significance, $F(1,17) = 3.59$, $p = .075$, $\eta_p^2 = .17$ (Figure 1). Participants in the AP-training group were more likely to select the top-left corner in the post-test than they were in the pre-test ($p = .016$, *Cohen's d* = 1.33) whereas those in the NP-training group were not ($p = .80$, $d = .09$).

Please insert Figure 1 about here

3.2. Overall Change in Anticipatory Performance

3.2.1. Response accuracy.

The 2 x 2 x2 ANOVA for RA revealed a significant 3-way AP-in-test x test occasion x training group interaction, $F(1,17) = 5.02$, $p = .039$, $\eta_p^2 = .23$, in the absence of main effects for AP-in-test, $F(1,17) = .03$, $p = .96$, $\eta_p^2 < .001$, for test occasion, $F(1,17) = 2.26$, $p = .15$, $\eta_p^2 = .12$, for training group, $F(1,17) = .35$, $p = .56$, $\eta_p^2 = .02$, or for any other interactions (ps > .11). The significant interaction shows that the two different training interventions resulted in different changes in RA depending on the presence of an action preference in the test (Figure 2; results for ΔRA are shown to aid interpretation). Training with an action preference was an advantage when anticipating throws from a player with an action preference in the post-test ($p = .027$, $d = .94$; one tailed in accordance with the a-priori hypothesis), but was a disadvantage when anticipating throws from a player *without* an action preference in the post-test ($p = .047$, d = .50; one tailed in accordance with the a-priori hypothesis). In contrast, training without an action preference had little effect on RA from pre- to post-test irrespective of whether the player did or did not have an action preference in the test ($p = .98$ and .53 and $d = .007$ & .28 respectively; two tailed).

Please insert Figures 2 & 3 about here

In light of these findings, we performed further testing to check whether the changes in RA were underpinned by changes in the ability to anticipate the *side* or the *height* of the opponent's throw. Specifically, we performed separate 2 x 2 x 2 ANOVAs on the percentage of trials where participants correctly anticipated the (i) side (right or left) and (ii) height (top or bottom) of the opponents throw. The results provided some tentative evidence to suggest that the changes in overall response accuracy were more likely to have been attributable to changes in the ability to predict height rather than side. The analysis for side revealed a significant test occasion x training group interaction, $F(1,17) = 5.98$, $p = .026$, $\eta_p^2 = .26$, and a main effect for AP-in-test, $F(1,17) = 8.26$, $p = .011$, $\eta_p^2 = .33$, in the absence of a 3-way interaction (Figure 3a), $F(1,17) = 1.31$, $p = .27$, $\eta_p^2 = .07$, or any other main or interaction effects, ps > .43. The test occasion x training group interaction shows that the AP-training group tended to improve their anticipation of the side of the throw while the

NP-training group became slightly worse. The analysis for height revealed a main effect for AP-in-test, $F(1,17) = 5.20$, $p = .036$, $\eta_p^2 = .23$, and a Test occasion x AP-in-test interaction, $F(1,17) = 5.23$, $p = .035$, $\eta_p^2 = .24$. The 3-way interaction was very close to significance (Figure 3b), $F(1,17) = 4.16$, $p = .057$, $\eta_p^2 = .20$, as was the main effect for test occasion, $F(1,17) = 3.80$, $p = .069$, $\eta_p^2 = .18$, with other effects not reaching significance, ps > .12. The borderline 3-way interaction reflects the improvement in the ability of the AP-training group to anticipate the height of the thrower with an AP, $p < .01$, $d = 1.41$, an effect that was not apparent for any of the other experimental conditions, ps > .10, ds < .51.

3.2.2. Response time.

The 2 x 2 x 2 ANOVA for RT revealed a significant 3-way AP-in-test x test occasion x training group interaction, $F(1,17) = 6.66$, $p = .019$, $\eta_p^2 = .28$, in the absence of main effects for AP-in-test, $F(1,17) = 1.79$, $p = .20$, $\eta_p^2 = .10$, for test occasion, $F(1,17) = .62$, $p = .44$, $\eta_p^2 = .04$, and for training group, $F(1,17) = 3.68$, $p = .07$, $\eta_p^2 = .18$. The only other significant interaction was between test occasion and training group, $F(1,17) = 6.20$, $p = .023$, $\eta_p^2 = .27$. The 2-way test occasion x training group interaction shows that training with an AP tended to improve RT in the post-test whereas training without a preference did not. However, the 3-way interaction (Figure 4) better explains this by showing that training with an action preference resulted in a significantly faster RT in the post-test when the thrower in the test did have an action preference ($p = .046$, $d = .76$), but not when the thrower did not have the action preference ($p = .50$ $d = .14$). In contrast, the RT did not change for those who trained without an action preference, irrespective of whether the player in the test did or did not have the action preference (p's = .12 and .33, d = .40 and .12 respectively). Crucially, these results show that the changes in response accuracy are a result of genuine changes in accuracy rather than being explained by a trade-off between accuracy and response time.

Please insert Figure 4 about here

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4. Discussion

The aim of this study was to examine how the ability to anticipate the outcome of an opponent's actions can be influenced by the action preferences of that opponent. We examined anticipatory performance before and after skilled handball goalkeepers took part in a training intervention where they viewed opponents who either did, or did not have, a preference to throw balls in one particular direction. Exposure to an opponent who did have an action preference during the training phase significantly altered the types of judgements made by observers during the test phase, and consistent with our hypothesis, we found that these changes altered the ability of goalkeepers to anticipate actions. More specifically, facing opponents with an action preference during training resulted in a commensurate increase in the ability to anticipate the actions of an opponent who continued to bias their throws towards their preferred direction, but resulted in a decrease in their ability to anticipate actions when the opponent no longer continued to throw towards their preferred direction. The examination of reaction times shows that these findings were not the result of a trade-off between time and accuracy; rather, both response time *and* accuracy were improved when there was congruence between the expected and actual outcome, and when the expected and actual outcome was incongruent, there was a decrease in accuracy without any change in response time. Taken together, these findings highlight that skilled observers use information about action preferences in an effort to enhance their anticipation of action outcomes, but that this information has the potential to be disadvantageous if the opponent acts inconsistently with the generated expectations of the observer.

The action preferences present during the training intervention resulted in clear differences in anticipatory performance in the post-test, and importantly, these differences were not the result of simple learning via exposure to the kinematic actions of the throwers. The very small change in response accuracy from pre- to post-test for the 'No AP in test or training' condition (mean ΔRA = +3.7%) shows that exposure to the actions during the training phase did not facilitate any significant perceptual learning. This result in itself may be seen to be in conflict with the majority of research that examines perceptual learning of anticipatory judgements, with results typically showing that training interventions result in direct improvements in anticipatory skill (e.g., Abernethy, Schorer, Jackson, & Hagemann, 2012; Farrow, Chivers, Hardingham, & Sachse, 1998; Williams, Ward, Knowles, & Smeeton, 2002).

However, considering that the participants in this study were already highly skilled rather than novice learners (as is the case in the majority of perceptual learning studies, though see Hopwood, Mann, Farrow, & Nielsen, 2011), the absence of any guiding information to facilitate learning (e.g., Hagemann, Strauss, & Cañal-Bruland, 2006; Ryu, Kim, Abernethy, & Mann, 2012; Savelsbergh, Gastel, & Kampen, 2010), and the short nature of the training intervention, it is not surprising that there were no significant improvements in anticipatory judgements in this study based on simple exposure to the kinematic actions of the throwers.

Having found that action preferences influence the anticipatory judgments of skilled performers in both a facilitatory and detrimental way, we separately calculated the response accuracy for the side and height of the throws in an effort to better understand the changes in behaviour. While not being entirely conclusive, the results suggest that the changes in anticipatory performance in the AP-training group were largely a result of changes in their prediction of the *height* rather than the side of the throws. It may be that anticipatory judgements of height are more difficult than those for side, and so skilled performers need to rely more on contextual information (like action preferences) to account for this less salient information. For instance, the height of a handball goal is shorter than its width, and so there is likely to be less variation in the movement pattern necessary to throw to the top and bottom of the goal when compared to that necessary to throw to the far left and right. If the kinematic information about height is less salient than that it is for side (e.g., Salmela & Fiorito, 1979; Savelsbergh, et al., 2002), then one would expect observers to rely more on contextual (prior) information as a result of the increased uncertainty in judgements of height (Körding & Wolpert, 2004).

Given the results of this and other studies (e.g., Farrow & Reid, 2012), it is clear that skilled performers are able to use patterns or biases in the actions of their specific opponents in an effort to enhance their performance in future anticipatory judgements. The ability to pick-up information about the action preferences of an opponent provides an important addition to the pool of informational sources that can be used by skilled performers to enhance the anticipation of action outcomes (see also Abernethy, et al., 2001; Alain & Proteau, 1980; Cañal-Bruland & Schmidt, 2009; Farrow & Reid, 2012; Loffing, Hagemann, & Strauss, 2010). Here we have shown that exposure to a particular pattern of preferred action outcomes can facilitate anticipatory performance, though importantly, this only seems to be the case

when the opponent continues to bias their actions in that particular direction. Crucially, this study shows that there is a disadvantageous flip side to the coin. That is, the pick-up of situational information can provide a distinct *disadvantage* under particular circumstances. We found a significant decrease in the response accuracy of anticipatory judgements when the goalkeepers were exposed to an opponent who had an action preference during training, but who no longer had a preference during the post-test. Gray (2002a, 2002b) has previously shown that skilled athletes use contextual information to generate expectations that can impair success when performing an action. Specifically, he demonstrated that a baseball batter's ability to hit a simulated fastball is impaired if that pitch is preceded by a series of three slower balls. This shows that expectations based on prior information can impair performance, and here we have extended this work by showing that these expectations can impair performance even when making anticipatory judgements.

There are a number of possible reasons (that are not necessarily mutually-exclusive) that could explain why there was a decrease in response accuracy when there was an action preference in the training phase but not in the test. First, it may be that the very salient information about action preferences gathered during the training phase simply distracted the goalkeepers from using the kinematic information they might typically rely on when making anticipatory judgements (as they probably did in the pre-test). In this sense the additional information may have interrupted what was likely to have been a well-learned response based on kinematic information from the movements of the opponent (e.g., Binsch, Oudejans, Bakker, & Savelsbergh, 2010). Also, the knowledge of the action preferences of the opponents may have altered the way that the participants *searched for* information when making their anticipatory judgements (e.g., Navia, et al., 2013). That is to say, the information may have altered the visual search patterns that performers relied on to anticipate the direction of the throw (or kick; Savelsbergh, et al., 2002). The registration of gaze behaviour in subsequent studies could help to establish whether this is the case. Closely related to this supposition is that the knowledge of action preferences could have drawn explicit awareness towards a task that is typically performed in a relatively implicit manner (Farrow & Abernethy, 2002). As a result, the act of becoming aware of and thinking about explicit information in itself may have interrupted automatic (implicit) processes that are characteristic for skilled performers. If, in addition, the explicit information about action

preferences is inconsistent with the kinematic information picked-up during the throwing action, it is even more conceivable that such explicit information may harm rather than support performance. One possibility to examine this explanation in the future could be to test participants under dual-task conditions (Masters, 1992) or to use experimental methods that measure cortical activity (Zhu et al., 2010). Further, it may be reasonable to expect to find differences in the way that performers of different skill levels use – and become susceptible to – contextual information like action preferences. This is another question worthy of further exploration, as one might expect lesser-skilled participants to be less adept at picking-up action preferences and so may be less susceptible to any detrimental effects of doing so.

A key difference between this study and the real-life football penalty situation raised earlier is that, rather than providing explicit information to participants about the action preferences of the throwers, we instead chose to implement a short training phase so participants could discover the situational information for themselves. In this sense participants were able to allocate their own sense of likelihood of a particular outcome being performed, rather than this information being enforced upon them. It is possible that 'passing on' contextual information could have a very different effect to when it is self-discovered by the performer. The exit questionnaire we used in this study was designed to see whether participants did detect the action preferences of the players they observed during the training phase. It is not surprising that, in the questionnaire, participants in the AP-training group correctly reported the action preferences of the throwers, particularly considering they received feedback after every trial during the training phase. What is more surprising though is that seven of the ten participants in the NP-training group reported biases in the directions of the throwers during the training phase even though such biases did not exist. This result could simply be a reflection of participants feeling that they needed to provide a positive response when asked in the questionnaire whether each thrower had a preferred throwing direction. Alternately, it might reflect the poor ability of humans to estimate statistical probability, a finding that is often reported across a range of different tasks (Alain & Proteau, 1980; Tversky & Kahneman, 1974). Considering that we have left participants to 'self-discover' the preferences by virtue of the training intervention, it would be interesting in future studies to compare whether probabilistic information about action

preferences has a similar effect on performance if participants were simply told about the action preferences. The concurrent measurement of participant confidence when making these judgements might be a useful addition to future studies to quantify the certainty of the judgements about action preferences being made by participants (Jackson, et al., 2006; Runeson, Juslin, & Olsson, 2000).

A particularly relevant issue related to the estimation of statistical probability is whether the pick-up of situational information necessarily needs to be a conscious process when responding with a motor action. In this study we examined the influence of action preferences on the ability to make perceptual judgements by asking participants to press a button corresponding to the likely direction of a throw. However, when playing, goalkeepers must use situational information in an effort to produce an *action* to save penalty throws. Very little is known about whether movements can be influenced by contextual information to a degree that is different to perceptual judgements based on the same information. It is possible that contextual information could differentially influence anticipatory judgements made by the perceptual and motor systems (see Masters, van der Kamp, & Jackson, 2007 for a demonstration of this effect in a different task). The level of anticipatory skill found when performing perceptual judgements tends to underestimate that found when performing motor actions (Farrow & Abernethy, 2003; Mann, et al., 2010), and so it might be reasonable to expect that knowledge about action preferences could lead to even stronger changes in response accuracy when producing a motor response, particularly when the time constraints imposed by the task become more demanding. Alternately, it is possible that the strong perception-action coupling inherent in a motor response may be more impervious to 'interruption' by situational information than a perceptual response, and so an action response may be less influenced by conscious knowledge of the action preferences of an opponent. It would be interesting to determine whether situational information (like action preferences) differentially influences perceptual and motor anticipatory judgements.

Based on the results of this study, it is worth reflecting back on the penalty situation in the Germany vs Argentina match to speculate about the most beneficial strategies to adopt in such a situation. From the perspective of the goalkeeper, it appears that knowledge of the action preferences of an opponent will prime the goalkeeper to anticipate a kick towards

that particular direction. This is likely to provide an advantage if the opponent continues to kick in that direction, but it is likely to place them at a distinct disadvantage if the kicker does not. Ideally, the goalkeeper needs to have some degree of certainty that their opponent will act consistently with their past behaviour. Conceivably information about the strength of the action preference, particularly in very important high-pressure or 'clutch' situations, might be useful in providing some reassurance about the likelihood the opponent will follow their action preference.

In contrast to the possible implications for the person viewing the action (in this case the goalkeeper), we can also ruminate about the potential lessons for the 'actor' performing the action (in this case the kicker). If the actor knows that their opponent is aware of their action preference, they would be best advised to act in a manner that is inconsistent with their previous behaviour. Of course this may be sound in theory; however, motor performers may possess a particular action preference because they are better versed at performing that given action. By altering their intention to perform a different, less proficient action, there is likely to be a subsequent decrease in the probability that the action will be successful. Clearly it is important for motor actors to invest time in enhancing their non-preferred motor actions for instances in crucial situations where they may be required.

Finally we can also put ourselves in the position of a coach who wishes to provide advice to goalkeepers attempting to save penalty kicks (or to athletes in similar situations in other sports). The coach might be best advised to only pass on information about action preferences to the goalkeeper if there is a strong bias in the actions of the actor: if there is only a weak preference to perform one particular action, yet the information is still passed on to the goalkeeper, then the goalkeeper may be unnecessarily primed to move in a direction that is not particularly likely to match the direction of the action. Further, if the coach does wish to pass on probabilistic information to a player, then it may be wise to do so without the opponent having explicit knowledge that they have done so. By walking on to the ground with a clipboard or computer tablet and blatantly showing it to the goalkeeper (or a goalkeeper pulling a piece of paper out of their sock), an opponent then may know that the goalkeeper is aware of their preference, and as a result they can react accordingly. With this in mind, a potentially wise coach could seek to fool opponents by giving the

impression that they are passing on information about action preferences (through the use of a clipboard or tablet), when in reality they actually pass no information on in the hope that the opponent might perform a less-preferred action, while ensuring that the goalkeeper is not primed to move in any given direction (e.g., see Memmert, Huttermann, Hagemann, Loffing, & Strauss, 2013).

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Tables

Table 1. Experimental design. In the pre- and post-test all participants anticipated the actions of a thrower with an action preference and a thrower without an action preference. For the participants in the AP-training group, both throwers seen during the training intervention had an action preference. In contrast, for the participants in the NP-training group neither thrower had an action preference during the training intervention.

Training group	Thrower	Percentage of throws to top-left corner of goal			Experimental condition
		Pre-test	Training intervention	Post-test	
AP-training	Thrower A	75%	75%	75%	AP in test and training
	Thrower B	25%	75%	25%	AP in training but not in test
NP-training	Thrower A	75%	25%	75%	AP in test but not in training
	Thrower B	25%	25%	25%	No AP in test or training

Figure Captions

Figure 1. Change in the percentage of 'top-left' predictions from pre- to post-test. Results are shown separately for the two intervention groups (AP-training and NP-training respectively) when tested viewing a player who did and did not have an action preference in the pre- and post-test. Error bars represent standard errors.

Figure 2. Change in overall response accuracy from pre- to post-test. Results are shown separately for the two intervention groups (AP-training and NP-training respectively) when tested viewing a player who did and did not have an action preference in the pre- and post-test. Error bars represent standard errors.

Figure 3. Change in response accuracy from pre- to post-test for predictions of (a) the side of the throw (right or left) and (b) the height of the throw (top or bottom). Results are shown separately for the two intervention groups (AP-training and NP-training respectively) when tested viewing a player who did and did not have an action preference in the pre- and post-test. Error bars represent standard errors.

Figure 4. Change in response time from pre- to post-test. Results are shown separately for the two intervention groups (AP-training and NP-training respectively) when tested viewing a player who did and did not have an action preference in the pre- and post-test. Error bars represent standard errors.

Figure 1

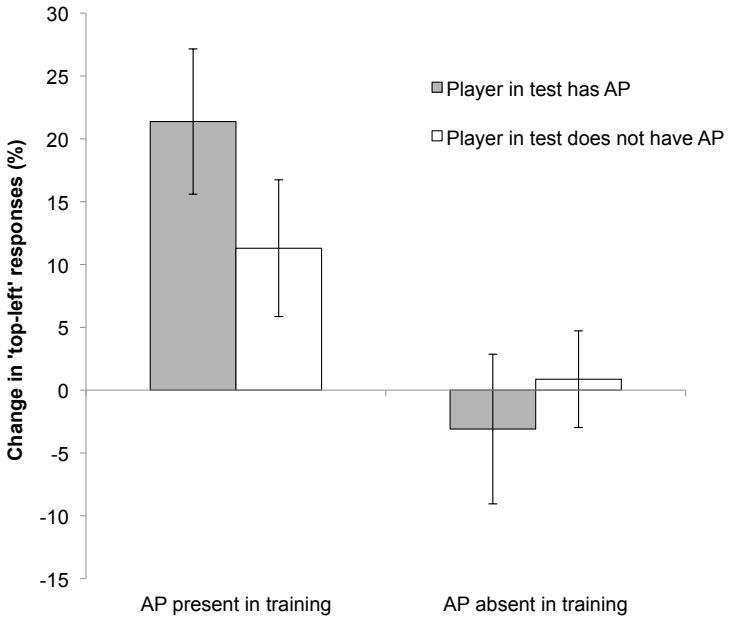

30
25
20
15
10
5
0
-5
-10
-15
Change in 'top-left' responses (%)
Player in test has AP
Player in test does not have AP
AP present in training
AP absent in training

Figure 2

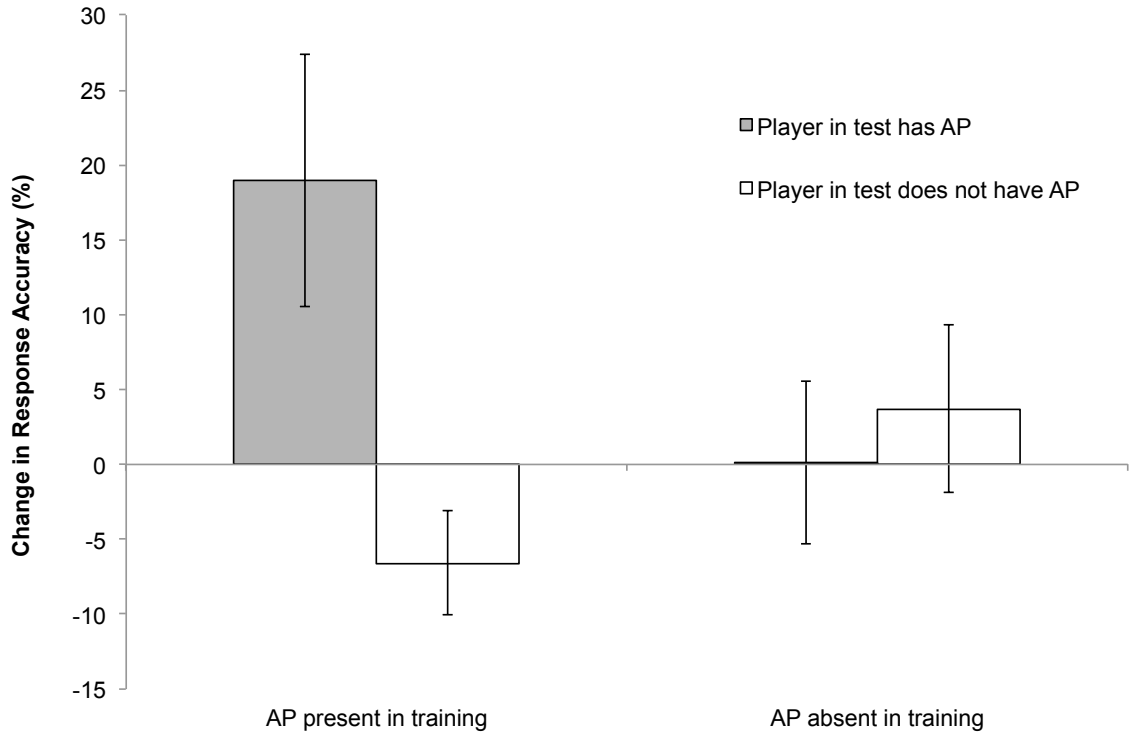

30
25
20
15
10
5
0
-5
-10
-15
Change in Response Accuracy (%)
Player in test has AP
Player in test does not have AP
AP present in training
AP absent in training

Figure 3

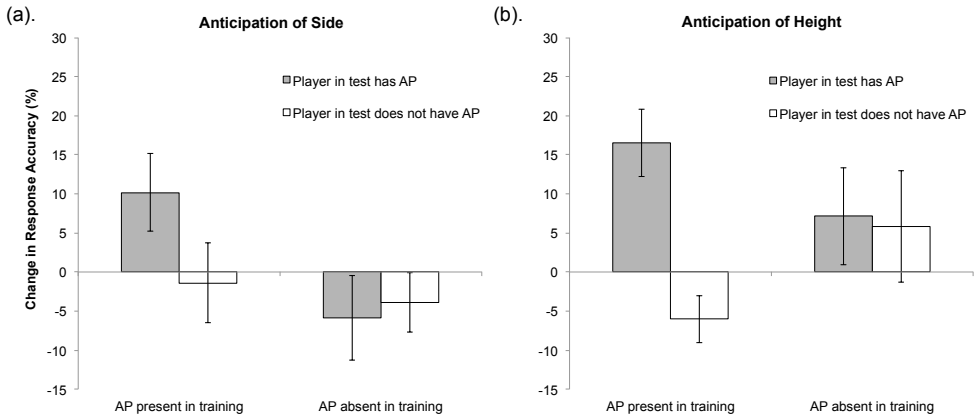
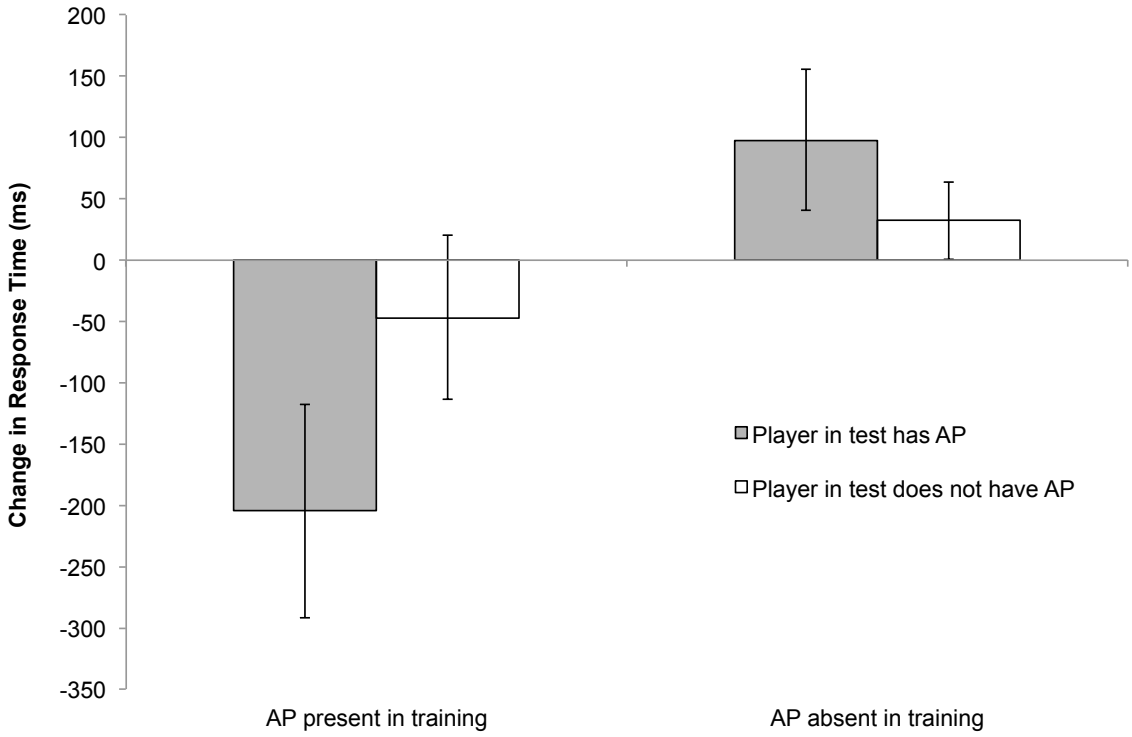

(a).
Anticipation of Side
Change in Response Accuracy (%)
30
25
20
15
10
5
0
-5
-10
-15
Player in test has AP
Player in test does not have AP
AP present in training
AP absent in training
(b).
Anticipation of Height
Player in test has AP
Player in test does not have AP
AP present in training
AP absent in training

Figure 4


200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
Change in Response Time (ms)
Player in test has AP
Player in test does not have AP
AP present in training
AP absent in training