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**Disguise and Deception of Action Outcomes Through Sports Garment Design Impair Anticipation Judgments.**

# Disguise and deception of action outcomes through sports garment design impairs anticipation judgments

RUNNING HEAD: DISGUISE AND DECEPTION

## Abstract

The ability to disguise and deceive action outcomes was examined by manipulating sports garments. In Experiment 1, those with higher and lower skill levels in anticipation predicted the throw direction of an opponent who wore a garment designed to disguise kinetic chain information. Higher skill anticipators were more adversely affected by the disguise garment than the lower skill anticipators, demonstrating that disguise removed the anticipation advantage. In Experiment 2, using the same occlusion methodology, the effect of deception was examined using two garments designed to create visual illusions of motion across the proximal to distal sequence of the thrower's action and compared to a white garment control. Performances for the deceptive garments were reduced relative to the control garment at the earliest occlusion points for the right-most targets, but this effect was reversed for the left-most targets at the earliest occlusion point, suggesting the visual illusion garments were deceiving participants about motion information from the proximal to distal sequence of the action.

# Deception and disguise of action outcomes through sports garment design impairs anticipation judgments

In fast paced ball sports athletes have to become very sensitive to the movements of opponents in order to find cues to anticipate their intentions. This ability to anticipate provides athletes with more time to move and prepare their response. Point light displays, deprived of surface gradients and textures have been used to show that intentions can be recognized without this information (Abernethy, Gill, Parks, & Packer, 2001; Ward, Williams, & Bennett, 2002). These published reports show that the relative motion profile of the action contains the information upon which intentions can be determined. However, the changing gradient of surface textures may play an important role in determining the kinematics of an opponent, an area not yet investigated in the literature. The skilled advantage in perceiving movement may be prone to break down when fundamental visual processes, such as those frequently described in the literature (Bruce, Green, & Georgeson, 2003), are disturbed.

In sport, the ability to develop the perceptual-cognitive skills that underpin the recognition of these motion patterns is thought to be a valid and reliable predictor of expertise (Aglioti, Cesari, Romani, & Urgesi, 2008). Therefore, disguising the relative motion of an action may disguise the intentions of an athlete and reduce the advantage afforded by these well-developed perceptual-cognitive skills to chance levels. In two experiments, we examine differences between the effects that deception and disguise have on the anticipation of throw direction. As an alternative to the conventional manipulations used in previous studies, with the aid of computer simulation or willful actions being performed for example, the design of three different garments were altered to disguise advance cues or deceive participants about the motion of body segments. The surface textures and motion of the garment worn by the actor were manipulated based on visual illusions known to effect fundamental visual processes (Bruce et al., 2003).

One of the first systematic investigations into deception and disguise in sport examined the ability of skilled and less skilled rugby players to anticipate the direction of an opponent's dribble with and without a deceptive movement (Jackson, Warren, & Abernethy, 2006). Less skilled players were found to be more susceptible to deceptive actions than skilled players. The primary focus subsequent to this seminal work has been on deceptive action in soccer (Smeeton & Williams, 2012), tennis (Williams, Huys, Canal-Bruland, & Hagemann, 2009), rugby (Brault, Bideau, Kulpa, & Craig, 2012), and basketball (Sebanz & Shiffrar, 2009). Thus far, there have been only a few published reports focusing on disguise (Rowe, Horswill, Kronvall-Parkinson, Poulter, & McKenna, 2009), presumably due to the methodological difficulties in concealing advance cues without having a consequential effect on linked body segments. Based on the definitions of Jackson et al. (2008) and others (Brault, Bideau, Craig, & Kulpa, 2010), we operationally define disguise as the concealing of genuine advance cues prior to the outcome of an action, such as ball-racket contact. This process is in contrast to deception, which we define as the presentation of counter predictive advance cues to fool an opponent about the outcome of an action. Evidence for disguise, therefore, would be present when a general decrease in anticipation accuracy relative to the control is seen, whereas deception would be evidenced by a reduction in anticipation accuracy that is specific to action outcome (e.g., left or right shot).

In two experiments, the surface texture of garments worn by an opponent was changed to either create an unnatural texture gradient cue to disguise an opponent's action outcome, or the illusion of motion to deceive an opponent action outcome. In the first experiment, the disguise manipulation was used to create 'visual noise', where luminance of the dark and light regions across their body changed as the opponent moved (Mather, 2006).

In the second experiment, a surface texture based on the Barber pole illusion (Wallach, 1935; (Sun, Chubb, & Sperling, 2015) was used to create a misperception about the movement of an opponent. In this illusion, diagonal straight lines rotating horizontally appear to move vertically. Both manipulations were designed to interfere with the use of genuine advance cues thought to be contained in the kinetic chain present in a thrower's action.

## Experiment 1

Published reports investigating advance cues in highly dynamic whole body discrete action have generally concluded that skilled athletes become sensitive to an opponent's movements arising from the kinetic chain (Abernethy, 1993; Abernethy & Zawi, 2007). The Kinematic Specification of Dynamics through biological motion perception presents one conceptual account of these affects (Runeson & Frykholm, 1983). The summation of rotational forces give rise to angular acceleration of body segments towards the end effector originating proximally (to the dominant axis of rotation) and evolving distally. This proximal to distal sequencing has been argued on the basis of evidence from spatial and temporal occlusion and eye movement studies (Smeeton, Huys, & Jacobs, 2013).

An alternative to the typical computer simulation approach is to change the perception of the action by making changes to the design of the garments worn by the sports performer. To date, only two published reports have illustrated the use of this approach. It has been reported that altering the properties of sporting garments can either have a facilitating (Causer, McRobert, & Williams, 2013) or debilitating (Causer & Williams, 2015) effect on anticipation judgments. For example, increasing the luminosity of postural cues known to be utilized by athletes detecting teammates' movements led to more accurate and faster anticipation judgments (Causer et al., 2013). Conversely, researchers have shown that by disguising these postural cues by utilizing patterns to offset perceived relative motion, anticipation performance can be significantly reduced (Causer & Williams, 2015). The advantage of this latter approach is that the usual action can still be performed without the characteristic movements of a ‘fake’ or ‘feint’. Sports garments containing visual illusions known to affect fundamental visual processes could give rise to the same misperceptions found in laboratory experiments, and in turn lead to impaired perception of an opponent’s kinematics. For example, ‘visual skill’ by way of the ocular-motor areas of the brain have been show to activate as a function of anticipation. Greater activation was seen in a network of areas associated with ocular-motor control using fMRI in participants high versus intermediate and low skilled in soccer (Bishop, Wright, Jackson, & Abernethy, 2013).

In the first experiment in this paper, perceptually skilled and less-skilled athletes watched video footage of a thrower direct a ball toward a target positioned to their left and right side. The throwing action was occluded at 160ms and 80ms before ball release, at ball release, and 80ms afterwards. The thrower wore two garments. The first garment was designed to effect the perception of angular acceleration by disrupting the extraction of large-scale spatial features (i.e., such as the orientation of the torso). Parallel lines with highly contrasting luminance, well-known to give rise to the perception of edges were printed onto the garment (Mather, 2006). High luminance and low luminance lines were printed on either side of ridges such that, when viewed from the same angle, the movement of the garment, and changing its orientation resulted in changes in the spatial frequency of the edges. This effect was expected to impair the process of spatial filtering known to be an important visual process in the extraction of features (Mather, 2006; Thurman & Grossman, 2011). The second garment was a white t-shirt that acted as a control. It was predicted that throw prediction accuracy in the perceptually skilled would reduce to the level of the perceptually less skilled (i.e., to chance levels) when viewing the ‘visual illusion’ garment and this effect would be more pronounced at the occlusion points immediately prior to, and at, ball release (i.e., before the availability of ball flight cues).

## Method

### Participants and design

A total of 40 intermediate level netballers (all female; mean age = 24.6 years, SD = 4.5) with a mean playing experience of 6.0 years (SD=3.2) were recruited. Participants watched 160 videos of a similar ability player throw a ball to the left and right side of a camera, filmed to recreate the perspective of an opponent intending to intercept a pass (mean stimulus length = 1960 ms, SD = 90). Footage was occluded at either 160 ms, 80ms before ball release, at ball release or 80 ms after ball release. The thrower wore the visual illusion sports garment designed to disguise the surface texture gradient of the body. This visual information has been shown to be important for visual perception of three dimensional structures (e.g., see Gibson, 1979). In a second condition, the thrower wore a white (control) sports top. Stimulus clips were displayed on a notebook computer screen (1366 x 768 pixels) with a 17 inch screen. The final frame of the occlusion conditions are presented in Figure 1. Both experiments were conducted in accordance with the ethics policy of the institution to which the first author was affiliated.

### Procedure

For each trial, participants were asked to indicate which direction (left or right) the ball would be thrown by pressing a button on the keyboard. Participants had 1.5 s to respond. The trials were presented in a random order and in 4 blocks of 40 trials. The order of blocks was counter-balanced across participants. For each participant, a percentage accuracy score was calculated based on the number of correct responses for the total number of trials, for each of the four occlusion conditions, for each of the two garments. A within-task criterion was used to create HIGHER and LOWER perceptual-cognitive skills groups based on the total accuracy scores from control condition at the 50th percentile median-split (Bishop et al., 2013; Huys et al., 2009).

**Analysis**

These data were analysed using a three-way, mixed-design ANOVA with Group (HIGHER, LOWER) as the between-participant factor and Garment (illusion [ILL], Control [CON]) and Occlusion (-160ms, -80ms, 0ms, +80ms) as the within-participant factors. Significant effects were followed up with Bonferroni corrected pairwise comparisons. Partial eta squared ($\eta_p^2$) and Cohen's *r* were used as measures of effect size where appropriate.

## Results

Figure 1 shows the effect of the visual illusion sports garment on percent accuracy of throw direction for the HIGHER and LOWER groups across the temporal occlusion points. There was a main effect of Group, $F(1, 38) = 40.70$, $p < 0.0001$, $\eta_p^2 = .52$, and Garment, $F(1, 38) = 15.93$, $p < 0.001$, $\eta_p^2 = .30$. On average, participants were 5.0% less accurate when facing the illusion garment than the control. The lower order interactions were superseded by the significant Group x Garment x Occlusion interaction, $F(3, 114) = 7.96$, $p < 0.0001$, $\eta_p^2 = .17$. In the HIGHER group, accuracy was higher when viewing the visual illusion sports garment compared to the control on the -80ms, 0ms and +80ms occlusions ($p < 0.05$), but not on the -160ms occlusion ($p > 0.05$). In the LOWER group, there were no differences between the visual illusion sports garment and the control garment on any of the occlusion conditions ($p > 0.05$).

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## Discussion

We examined the effect of a disguise visual illusion garment on throw prediction accuracy. As predicted, disguising the action outcome using a visual illusion sports garment impaired the perception of cues and reduced judgment accuracy in high-skilled participants. Those with higher skill levels showed decrements in performance at the -80ms, 0ms +80ms occlusion points. These higher skill individuals appear to be particularly sensitive to this motion disguise. Their ability to perceive the outcome of their opponent drops, whereas the less skilled group did not differ. We speculate that the perception of the trajectory of the body movement was impaired by the garment design and as a result the ability of the higher skilled participants to perceive information present in the kinetic chain that would usually be used to anticipate throw direction. This result is consistent with the one previous study investigating disguise through garment design showing skilled anticipators are more susceptible to disguise (Causer & Williams, 2015) and other studies on disguise (e.g. Rowe et al., 2009).

The manipulation used in this experiment was designed to impair the perception of body movement through known effects of luminance grating changes on spatial filtering. Whilst the approach to examining disguise is consistent with others in the literature, some caution should be adopted in interpreting the results as clear evidence for a disguise effect. There may have been some element of deception present in the stimuli. An analysis that compares accuracies of different throw directions is needed to examine this possibility. To investigate deception a new manipulation was created in order to lead to a misperception of motion, a defining feature of deception. Previously, the presence of kinematic features designed to fool an opponents about an action outcome have been shown to lead to misperception (Brault et al., 2012; Lopes, Jacobs, Travieso, & Araujo, 2014; Smeeton & Williams, 2012). The misperception of specific kinematic features therefore was expected to lead to misperception of action outcomes in Experiment 2.

## Experiment 2

In Experiment 2, we examine the mechanisms of deception by aiming to alter the perception of motion of the thrower. A previous study investigating anticipation in handball throwers has shown that artificially decoupling left and right body segments impairs anticipation performance in both skilled and less skilled throwers (Bourne, Bennett, Hayes, Smeeton, & Williams, 2013). Therefore, the manipulation aimed to decouple this sequence of the action, and was based on the Barber pole effect (Wallach, 1935). By using this visual illusion as a theoretical backdrop to our manipulation we expected movement perception could be changed and counter-predictive advance cues presented would 'fool' opponents about the outcome of an action. The Barber pole illusion leads to the perception of motion tangential to the direction of movement (e.g., vertical motion is perceived from the horizontal rotational movement of a continuous line around cylinder sloping at a 45° to the axis of rotation). The garment was designed to lead to the misperception of the rate of body rotation movement (see Figure 2) such that the horizontal rotation of the hips required to perform the throwing action would be accompanied by a perceived increase in vertical movement. Therefore, more rotational motion would be perceived as vertical motion and as a result, the hips to shoulder linkage would be misperceived to not have rotated as much as they actually had. Based on this rationale, it was expected, that for a right-handed thrower, anticipation accuracy for targets requiring more body rotation (i.e. rightward to the defender facing the thrower) would be decreased relative to the control but not those requiring less rotation (i.e. targets leftward of the defender). Second, another version of the Barber pole illusion manipulation was designed to disrupt the perception of proximal to distal summation of forces through the kinetic chain while controlling for the pattern design. A looser fitting half-t-shirt containing the same pattern was worn over the top of the first that moved more freely across the under t-shirt such that the translation of hip-to-shoulder rotation would be less apparent than the other garment conditions. The effect was expected to dissociate the body rotation in the hip-to-shoulder linkages having the effect of perceiving a delay in the proximal to distal sequence in the kinematic chain while the surface pattern across the two garments did not change. This effect was expected to lead to impaired anticipation accuracy toward the right of the defender, but not targets to the defender's left earlier in the throwing action due to the hips and shoulders being informative for anticipating earlier in the action (Ward et al., 2002; Williams, Ward, Knowles, & Smeeton, 2002). A third white garment acted as a control. Four target location conditions were used to increase the sensitivity to throw direction (Far Left, Near Left, Near Right and Far Right, from the perspective of a defender facing the thrower tasked with intercepting the thrower's pass) and enable measurement of counter predictive advance cues. To further increase the sensitivity of the experiment to the temporal occlusion manipulations higher, medium, and lower skill groups of participants were created. Sensitivity of higher, medium and lower skill groups to deceptive actions has been shown to vary across -160ms, -80ms, 0ms and +80ms occlusion points (Bishop et al., 2013).

It was predicted that throw prediction accuracy would be reduced in the visual perception garments relative to the white control garment with the greatest effect seen in the garment that separated the kinetic chain the most because artificially decoupling of body segments has been shown to impair anticipation performance in both skilled and less skilled throwers (Bourne et al., 2013). Additionally, as evidence for deception, we expected decrements in prediction accuracy relative to the control to be specific to throw direction targets. That is, this accuracy would be reduced the most at the rightmost target where the separation of the kinetic chain is thought to be the greatest, and increased the most in the leftmost target where separation is the least. However, if the visual perception manipulation disguised advance cues then this decrement in throw performance would occur uniformly across all target locations.

# Method

## Participants and design

The effect of using a visual illusion sports garment to disguise and deceive intention of a netball thrower was compared between netballers with higher, medium and lower perceptual-cognitive skill. A total of 30 intermediate level, netballers (all female; mean age = 22.3 years, SD = 3.5) with a mean playing experience of 6.3 years (SD = 2.9) participated. All played for a club and no one played regional standard or above. None of these participants had taken part in Experiment 1. Participants watched 192 videos of a matched ability player throw a ball to Far Left, Near Left, Near Right and Far Right of the camera. The player wore three different garments (see Figure 2). The first two were designed to deceive the opponent about the intended throw direction based on the Barber pole illusion, or the thrower wore a white (control) garment. All other aspects of the design were the same as Experiment 1.

## Procedure

For each trial, participants were asked to indicate which direction (Far Left, Near Left, Near Right or Far Right) the thrower would direct the ball. A within-task criterion was used to create HIGHER, MEDIUM, and LOWER perceptual-cognitive skill groups based on the total accuracy scores from control condition at the 33$^{rd}$ percentile median-split. All other procedures were the same as Experiment 1.

## Analysis

The accuracy scores (%) were analyzed using a four-way, mixed-design ANOVA with Group (HIGHER, MEDIUM, LOWER) as the between-participant factor and Garment

(Body rotation [BODY] Body rotation and kinetic chain [BODY+CHAIN], Control [CON]), Direction (Far Left, Near Left, Near Right or Far Right) and Occlusion (-160ms, -80ms, 0ms, +80ms) as the within-participant factors. Significant effects were followed up with Bonferroni corrected pairwise comparisons. Partial eta squared ($\eta_p^2$) and Cohen's *r* were used as measures of effect size where appropriate.

**Results**

There was a main effect of Garment, $F(2,66) = 8.363$, $p < 0.01$, $\eta_p^2 = .17$. On average, the lowest accuracy scores were recorded for the BODY+CHAIN visual illusion garment (51.3% SE 1.3) compared to BODY visual illusion (55.0% SE 1.6) and the control garment (56.8%, SE 1.7), *ps* < 0.05. There was a main effect of Direction, $F(3,99) = 17.581$, $p < 0.0001$, $\eta_p^2 = .347$. On average, participants were significantly more accurate when anticipating throws to the Far Left target (72.7%, SE=3.7) than the Near Left (47.8%, SE=2.4), Near Right (54.7%, SE=2.4) or Far Right targets (42.4%, SE=3.3). No other differences between throw directions were found. There was a main effect of Occlusion $F(3,99) = 77.013$, $p < 0.0001$, $\eta_p^2 = .700$. On average, there was a significant difference between -160ms (41.4%, SE=1.1) and -80ms (50.8%, SE=1.4), which in turn was different to 0ms (61.6%, SE=1.9), but 0ms was not different to +80ms (63.9%, SE=2.0). There were no significant effects involving Group and the Group main effect was not significant, $F(2,33) = 0.667$, $p > 0.05$, $\eta_p^2 = .039$. However, the Group X Garment X Direction interaction approached the alpha level of significance ($F(8.320,137.281) = 1.979$, $p = 0.051$, $\eta_p^2 = .107$. There was a Garment X Direction effect, $F(6,198) = 12.251$, $p < 0.0001$, $\eta_p^2 = .271$. This effect showed that throw prediction accuracy for the two visual illusion garments was below that of the control in the Far Right target location and above that of the control in the Far Left target location.

Other lower order interactions were superseded by a significant Garment x Direction x Occlusion interaction, $F(18,594) = 3.850$, $p < 0.0001$, $\eta_p^{\,2} = .104$. This interaction has been plotted in Figure 3. For throws to the Far Left, early in the action (i.e. -160ms) accuracy for both the BODY and BODY+CHAIN garments were significantly greater than the control. Later in the action the BODY garment was anticipated significantly more accurately than the other two garments (i.e., 0ms). For the Near Left target, no significant differences between garments were seen early in the action (i.e., -160ms to -80ms), but anticipation accuracy in the BODY and BODY+CHAIN garment was significantly lower than the control later in the action (i.e., 0ms). For the Near Right target, accuracy was significantly lower in the BODY+CHAIN garment compared to the BODY and control but not from each other (i.e., -80ms). This BODY+CHAIN difference with BODY and control was no longer found in the later stages of the action (i.e., 0ms to +80ms). Finally, for the Far Right target, both BODY and BODY+CHAIN garments were anticipated with significantly less accuracy than the control particularly in the early stages of the action (i.e., -160ms to -80ms).

## Discussion

We examined the mechanisms of deception by altering the design of the throwers garment. It was predicted that throw prediction accuracy would be reduced in the visual perception garments relative to the white control garment with the greatest effect seen in the garment that effected the perception of the kinetic chain. Additionally, we expected decrements in prediction accuracy relative to the control to be specific to throw direction targets. Overall, the prediction accuracy of the BODY+CHAIN garment was 6% less than the control and 4% less than the BODY garment, indicating the BODY+CHAIN garment lead to successful manipulation of the information used to make throw accuracy predictions. Additionally, there was a Garment X Direction interaction indicating that anticipation performances when viewing the visual illusion garments were below that of the control in the

Far Right target location and above that of the control in the Far Left target location. Overall, the relative decline in accuracy when viewing the visual illusion garments was not consistent across the left to right targets relative to the control, suggesting that these visual illusion garments lead to deception rather than disguise. Finally, there was a significant Garment X Target Direction X Occlusion interaction. This 3-way interaction showed that the Garment X Direction interaction effect was more pronounced at the earlier occlusion time points, indicating that the effect resulted from the movement of the thrower prior to ball release. Taking the results of these interactions together, and because the effect was not consistent across throw directions, evidence of a deception effect was found. The most likely cause is that the visual illusion garments lead to misperception of body rotation and information from the movement of forces throughout the kinetic chain. The proximal to distal summing of rotational force leading to the angular acceleration of limb segment is thought to provide important kinematic information for anticipating the resultant direction of a projectile in highly dynamic whole-body actions (Abernethy, 1993; Abernethy & Zawi, 2007). Presumably, the misperception of body rotation and the misperception of the linkage between the rotation of the hips and the shoulders earlier in the action sequence was perceived as the shoulders rotating to a lesser extent, or rotating later in the action, than actually occurred. As a result, more throws were perceived as being directed to the left targets rather than the right ones.

Although a skill effect was reported in Experiment 1, there was a non-significant tendency for skill to interact with direction and garment ($F(8.320,137.281)=1.979$, $p = 0.051$, $\eta_p^{2} = .107$). Plausible reasons for a lack of an effect are the change from using a within task criterion to separate groups and the adoption of three, rather than two different skill levels. Additionally, the decoupling of the movement segment between left and right side of the throwers action may have reduced the skill effect. By decoupling the motion of the left and right side of the body by 20% of the total throw time has been shown to reduce the ability to anticipate throw direction of skilled performer to that of less skilled (Bourne et al., 2013).

## General Discussion

In this paper, we report two experiments that examined differences between the effects of disguise and deception on the anticipation of throw direction. Three different garments were used with the intention of disguising advance cues or deceiving participants about the motion of body segments. These manipulations were expected to effect the perception of the angular acceleration of body segments resulting from the kinetic chain moving proximal to distal of the end effector. For the first time, the surface textures and motion of the garment worn by the sporting actor were manipulated based on visual illusions known to effect fundamental visual processes (Bruce et al., 2003; Mather, 2006; Sun et al., 2015; Thurman & Grossman, 2011).

In Experiment 1, prediction accuracy was reduced in a group of higher skill perceivers to that of a group of lower skill perceivers when they watched a thrower wearing a garment where the rotational movement of the throw resulted in changes in high contrast lines in close proximity to each other. This effect was present -160ms and -80ms before ball release, an effect consistent with other studies containing disguising actions (Causer & Williams, 2015; Rowe et al., 2009). In Experiment 2, it was found that the visual illusion manipulations, based on the Barber pole illusion (Sun et al., 2015; Wallach, 1935), were successful at deceiving perceivers about throw outcome. Accuracy was reduced across throw target locations from left to right in the visual illusion garments, but not in the control garment. Moreover, this effect was more pronounced at earlier occlusion periods, and no large and significant skill effects were found. This is the first investigation of deception using sport garment design, and while others have shown deception to be more pronounced early in the action sequence (Bishop et al., 2013), the use of more sensitive measures by increasing the number of response categories to study deception has allowed the specific effects of the deceptive manipulation to be measured. Such an approach may lead to further insights into the anticipation process as highlighted elsewhere in the literature (Stevenson, Smeeton, Filby, & Maxwell, 2015).

This is the first time that the approach used to examine disguise has been compared with deception in one study. The results suggest that there is a qualitative difference between disguise and deceptive advance cues. The disguising of advance cues appears to have more general effects on the perception of advance cues such that the ability to pick up information for anticipation is reduced. There was also a larger effect size for disguising garments $\eta_p{}^2$ = .30 than deceptive garments $\eta_p{}^2$ = .17. Whilst direct comparison of the garments is needed, presumably, the information residing in the advance cues is concealed in disguised actions (Brault et al., 2010). In deceptive actions, there is a specific effect on anticipation accuracy such that accuracy is increased to one target location but is reduced in another. The misperception of motion results in the perception of counter-predictive advance cues. Participants are more accurate at anticipating one outcome direction compared to another. This distinction between disguise, which effects all outcome directions, and deception, which effects specific outcomes may provide an objective way of testing between disguise and deception processes, a distinction which still is a source of debate since Jackson et al. (2006) conducted the first systematic study of deception (Jackson et al., 2006). Whilst it is not clear why a skill effect was not found in Experiment 2, one plausible reason is that the experimental manipulation affected fundamental visual processes (the barber pole effect is experienced by many) as a result it may have neutralized, or at least largely diminished the skill effect typically found in the literature. However, a reason for the Group X Garment X Direction effect only approaching significance may have been due to the reduced statistical power resulting from the increase from two groups to three. Alternatively, it may be the case that the within-task criterion used for selecting dichotomous skill groups may result in loss of information. The relationship between anticipation the outcome variables of garment and throw direction may be lost. Some have expressed caution about using this dichotomous approach and recommend a regression analysis to preserve this type of information (Altman & Royston, 2006).

These results may have an important practical impact on applied anticipation interventions and research. The typical approach to investigate the informational value of certain body regions for anticipating outcomes is to spatially occlude the region. The resulting effect of this manipulation is that skilled performers then extract information from other regions in order to anticipate outcomes (Huys et al., 2009; Smeeton et al., 2013). However, an important difference between previously published reports and the current approach is that the disguise manipulation reduced performance to that of the less skilled anticipators negating their ability to anticipate even when other body regions were visible. Therefore, when learning to anticipate, the use of occlusion may promote the search for alternative information. However, the use of garments to increase the ambiguity of information may lead to continued impaired performance. Being aware of the occlusion may constrain or facilitate search for alternative regions to extract information, but increasing the ambiguity of the movement of body regions through garment design may not. The use of garments makes it possible to disguise or deceive actions in the absence of intentional movements to do so.

Previous approaches to understand disguise and deception have used movements, such as a fake of feint in rugby (Brault et al., 2012) or basketball (Sebanz & Shiffrar, 2009) or exaggeration in soccer (Smeeton & Williams, 2012) or artificially manipulated actions through computer simulation (Huys, Smeeton, Hodges, Beek, & Williams, 2008). The presence of disguise or deceit in the absence of intention to do so may result in a reduced ability of an observer to pick up disguise or deception, thereby increasing the effect of this disguise or deceit. The effect may occur because the observer is not alerted to the disguise or deceit and, as a result, stop the typically observed change from less conscious more conscious awareness, which typically occurs in intentional deception (Jackson et al., 2006; Smeeton & Williams, 2012). For example, when actors intentionally deceive observers, activation of the right anterior cingulate cortex, an area associated with error detection, in the brains of skilled anticipators when viewing deceptive actions has been found to be more active than other lower skill groups (Bishop et al., 2013). Furthermore, brain activations are consistent with the identification of deception in sport requiring more cognitive effort (Wright, Bishop, Jackson, & Abernethy, 2013). What is not known is, when the perception of body movement is changed without the actual movements changing and presumably intentionality not being present then, is this change in awareness absent? If so, then one's normal ability to detect disguise and deception may be impaired.

In the case of deception, when a deceiving movement is contained in the action all skill groups are impaired (Brault et al., 2012; Jackson et al., 2006; Smeeton & Williams, 2012; Williams et al., 2009). However, the use of deception will typically result in misperception and error monitoring (Bishop et al., 2013). What it not clear is whether or not the use of deceptive visual illusions, that effect 'bottom-up' fundamental visual processes such as feature extraction and motion perception, will result in a performance decline that is impenetrable to 'top-down' processes such as cognitive effort, executive function, and explicit learning. If this impenetrability is found to be correct, then the use of visual illusions in the form of garment design could have a profound effect by neutralizing the expert anticipation advantage they have come to enjoy and, potentially raise questions about the ethics of using these garments in competitive sport.

From a practical perspective, the disguise-based garment had a generic effect on anticipation accuracy, whereas deceptive garments impair accuracy to perceive throw direction, but as a consequence increase the accuracy towards another direction. Therefore the impact of the deceptive garments on performance success using this garment pattern is dependent on the throw direction. Similarly, the differences in body rotation direction between left and right arm throwers may reverse the effects of the deception manipulation. The clockwise rotation of the garment for a right-handed thrower produced the misperception of the kinetic chain. It is predicted that if a left-handed thrower was used with a corresponding patterned garment then the opponent directional effect would be found.

Whilst this study used netball throwers, it is expected that these effects would be seen in other sports where anticipation of a projectile struck or launched is important for performance. In these sports, such as tennis, football, baseball and cricket, the perception of information for anticipation has been shown to arise from the proximal to distal changes in the opponents kinematics thought arise from the summation of forces across the kinetic chain. A final note of caution is expressed concerning these practical implications. The response mode used in these experiments was a button push and the experimental stimulus was presented on a relatively small two-dimensional computer screen. Some researchers have questioned the ecological validity of these methods (Dicks, Button, & Davids, 2010), although further research is needed to substantiate these claims.

In conclusion, we report that both disguise and deception of advance cues can be achieved through modifying the garments worn by athletes. The disguise garment was effective at reducing anticipation accuracy prior to the availability of ball flight, and impaired the perception of advanced cues. The deception garments were successful at causing misperception of advance cues across the kinetic chain leading to a higher anticipation performances for left most targets and lower anticipation performance for right most targets at the earlier time points in the throw. The questions of whether these effects are cognitively impenetrable, and if perceptual-cognitive training can be used to overcome these negative effects, have yet to be addressed and are worthy topics for future research.

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## Figures

*Figure 1*. Judgment accuracy scores from the higher perceptual-cognitive (HIGH) and lower perceptual-cognitive skills (LOW) groups while observing the visual illusion (ILL) and white control (CON) sports garments when stimulus trials were occluded at 160ms, 80ms, 0ms before, and 80ms after ball release. The top four panels show the final frame from the ILL condition and bottom the CON condition at the four occlusion points. Error bars represent standard error.

*Figure 2*. Stimulus footage across the four occlusion conditions (-160ms, -80ms, 0ms, +80ms) for the three garment conditions (CON=Control, BODY=Body Rotation Illusion, BODY+CHAIN=Body Rotation Illusion and Kinetic Chain Separation.

*Figure 3*. The Garment X Occlusion X Direction interaction. The garments are represented by the CON= White garment control, BODY= Barber pole illusion garment and BODY+CHAIN= Barber pole illusion garment with separation of the hips and shoulders. Directions are represented by FL= Far Left, NL= Near Left, NR= Near Right and FR = Far Right target locations. Error bars represent standard error.