Earlier Detection Facilitates Skilled Responses to Deceptive Actions

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Abstract

High-skilled and recreational rugby players were placed in a semi-immersive CAREN Lab environment to examine susceptibility to, and detection of, deception. To achieve this, a broad window of seven occlusion times was used in which participants responded to life-size video clips of an opposing player 'cutting' left or right, with or without a deceptive sidestep. Participants made full-body responses to 'intercept' the player and gave a verbal judgement of the opponent's final running direction. Response kinematic and kinetic data were recorded using three-dimensional motion capture cameras and force plates, respectively. Based on response accuracy, the results were separated into *deception susceptibility* and *deception detection* windows then signal detection analysis was used to calculate indices of discriminability between genuine and deceptive actions (*d'*) and judgement bias (*c*). Analysis revealed that high-skilled and low-skilled players were similarly susceptible to deception; however, high-skilled players detected deception earlier in the action sequence, which enabled them to make more effective behavioural responses to deceptive actions.

Keywords: deception, susceptibility, detection, discriminability, bias

1. Introduction

A key challenge for performers when anticipating actions and their outcomes is to judge whether the intent conveyed by their opponent is genuine or fake (Jackson et al., 2018). It is now well established that expert players judge the outcomes of deceptive actions more accurately than their lesser-skilled counterparts (Güldenpenning et al., 2013). However, inferences about relative susceptibility to deception have been made from a time window in which player accuracy increases rapidly from the point at which they have already been deceived (Jackson & Cañal-Bruland, 2019). The degree of improvement shows how well players *detect* deception but does not reveal their relative *susceptibility* to deception. Consequently, researchers have a good understanding of how and when players detect deception but limited understanding of the temporal characteristics of how they become deceived. In the present study, we use the conceptual and empirical distinction between the time window in which performers become deceived – 'deception susceptibility' – and the window in which they detect deception – 'deception detection' to examine the whole time window of deception (Warren-West & Jackson, 2020).

The ability to anticipate an opponent's intentions enables skilled sports performers to make accurate and well-timed responses in time-constrained tasks (Abernethy et al., 2007; Gabbett & Abernethy, 2013; Triolet et al., 2013). However, their greater sensitivity to advance visual information potentially leaves them more vulnerable to spurious or misleading information (Güldenpenning et al., 2013; Jackson et al., 2006). In almost all studies of deception to date researchers have focused on deception detection and a strong body of evidence supports the expert advantage across numerous sports, using different research designs and judgement criteria. For instance, an expertise effect has been documented for direction judgements in racket sports (Huys et al., 2009; Rowe et al., 2009; Williams et al., 2009), genuine and deceptive football penalty kicks (Dicks et al., 2011; Lopes et al., 2014; Smeeton & Williams, 2012), go/no-go judgements of handball penalty throws (Alsharji & Wade, 2016; Cañal-Bruland & Schmidt, 2009), differentiation of smash and poke shots in volleyball (Güldenpenning et al., 2013), the influence of gaze (mis)direction when judging basketball passes (Kunde et al., 2011; Sebanz & Shiffrar, 2009), differentiation of genuine and 'stepover' football actions (Jackson et al., 2018, 2020; Wright et al., 2013), and differentiation of genuine and 'sidestep' rugby actions (Brault et al., 2012; Jackson et al., 2006; Lynch et al., 2019; Mori & Shimada, 2013)

To understand the influence of deceptive actions on response accuracy as actions unfold, many researchers have employed the temporal occlusion paradigm. For instance, skilled rugby players showed a much sharper increase in response accuracy than novices shortly after the footfall that initiated the fake change of direction (Mori & Shimada, 2013). The same effect was seen in studies using sidesteps presented in a virtual environment (Brault et al., 2012) and in full video and point-light videos of soccer stepovers (Jackson et al., 2018). By analysing the kinematics of deceptive and genuine actions in this time window, researchers have argued that expert players are less susceptible to deception because they are more attuned to honest signals (e.g., hip yaw and centre of mass displacement), whereas novices are more sensitive to deceptive signals (e.g., head and upper trunk yaw, Brault et al.). However, this inference is questionable because performers had already been deceived at the start of the time window that was analysed. Consequently, the visual information specified in this window was that which participants used to *detect* deception rather than the information that *caused* players to be deceived.

To measure susceptibility to deception, earlier times of occlusion should be used to show where response accuracy for deceptive actions falls below chance. The proportion of correct responses on genuine actions ('hits') and the proportion of incorrect responses on fake trials ('false alarms') can then be used to calculate separate indices of the ability to discriminate between genuine and fake actions (*d'*) and participant bias toward judging actions to be genuine or fake (*c*) (Cañal-Bruland & Schmidt, 2009; Jackson et al., 2018; Warren-West & Jackson, 2020). While the source of response bias might be cognitive, for example reflecting knowledge about the relative frequency of genuine and fake actions, the use of multiple times of occlusion reveals perceptually driven changes in the tendency to judge actions to be genuine.

Collectively, measures of response accuracy, discriminability, and bias provide a comprehensive set of outcome measures for pinpointing changes in the effectiveness of deceptive actions across time. Specifically, increased susceptibility to deception across times of occlusion in a direction judgment task (left, right) will be indicated by (1) a decrease in response accuracy for deceptive actions, (2) an increase in response bias toward judging actions to be genuine, and (3) little or no improvement in the ability to discriminate between genuine and deceptive actions. Conversely, as the opponent's true intention is revealed and deception is detected one would expect to see an increase in response accuracy for deceptive actions, a reduction in bias toward 'genuine' responses, and an increase in discriminability between genuine and deceptive actions. If high-skilled performers are less susceptible to deception, they should maintain higher discriminability than low-skilled performers in early times of occlusion. Alternatively, if earlier detection of deception reflects a broader phase shift in response accuracy, then earlier detection of deception by higher-skilled performers would be offset by earlier susceptibility to deception. Inspection of response accuracy data from a study of sidestep actions provides preliminary support for the ‘phase shift’ hypothesis (see Figure 3 in Mori & Shimada, 2013). Rugby players showed better detection of the double sidestep – an action containing three changes of direction – than novices, reflected in a sharper increase in response accuracy; however, their accuracy was *lower* than novices in the 200ms preceding the second sidestep. This interpretation is potentially confounded by skilled players’ greater responsiveness to the initial sidestep, which had the effect of reducing outcome accuracy at early occlusion points on double-sidestep trials. To test the competing predictions while addressing this confound, Warren-West and Jackson (2020) compared high-skilled and recreational rugby players’ ability to discriminate between genuine actions and single sidestep actions using eight times of occlusion across a 700ms window. They found no evidence of a phase shift in response accuracy; rather, high-skilled players were both less susceptible to deception and better able to detect it. This was evidenced by higher discriminability between genuine and deceptive actions in the earliest occlusions.

While Warren-West and Jackson (2020) provided empirical evidence that higher-skilled players are more resistant to deception, a limitation is that participants viewed the test on a small screen and made key-press responses, which are unrepresentative of responses in actual encounters. Many researchers have employed verbal (Abernethy, 1990; Jackson & Mogan, 2007), pen and paper (Abernethy & Russell, 1987; Huys et al., 2009; Smeeton & Williams, 2012), and button-press responses (Helm et al., 2020; Kunde et al., 2011; Sebanz & Shiffrar, 2009) and have shown that expertise effects are similar across response formats in tests of anticipation (Farrow et al., 2005) and deception (Brault et al., 2012; Lynch et al., 2019). Conversely, other researchers found that expertise effects were more pronounced when participants made more representative responses (Alsharji & Wade, 2016; D. L. Mann et al., 2010).

This might be particularly important for studying more subtle responses to deceptive actions. For example, verbal and button-press responses are unlikely to capture the sense of being ‘wrong-footed’ by a deceptive action. In addition, there is evidence that visual behaviour differs across test formats (Belardinelli et al., 2015; Danion & Flanagan, 2018; Dicks et al., 2011).

Researchers have demonstrated that high-skilled rugby players spend a greater proportion of time viewing the hip region of an opponent when judging genuine and deceptive actions, in comparison with less-skilled and novice players (Mori & Shimada, 2013; Warren-West & Jackson, 2020). By examining the relationship between visual search behaviour and response accuracy, researchers have made inferences about which visual sources cause deception, and which are used to detect deception. As high-skilled performers have been shown to utilise more efficient search strategies (Piras et al., 2014), scientists have argued that high-skilled rugby players are more attuned to ‘honest’ visual cues aligned to the centre of mass (hip region and lower trunk), and are, therefore, less distracted by deceptive signals, suggested to be found predominantly at the head and feet of the opponent (Brault et al., 2012).

The aim of the present study was to combine the realism and experimental control afforded by life-size video displays with a comprehensive analysis of realistic responses to investigate initial susceptibility to, and subsequent detection of, deception. To accomplish this, we used a large-screen temporal occlusion paradigm with seven times of occlusion that spanned the whole window in which deceptive actions took effect. At each time of occlusion, verbal response accuracy data were used to calculate measures of discriminability and response bias and we recorded the frequency, accuracy and magnitude (horizontal displacement) of physical responses. We hypothesise that high-skilled players will be less susceptible than recreational players to deception, reflected in higher discriminability and lower perceptual bias toward judging actions to be genuine. Second, in line with previous research on skilled responses during interceptive tasks, we hypothesise that high-skilled players will make fewer physical responses in early-occluded trials as they wait for later information to initiate their response (Dicks et al., 2011). Third, we hypothesise that the high-skilled players will make fewer initial (incorrect) responses and will follow this with later (correct) responses of greater displacement. Regarding detection of deception, we hypothesise that high-skilled players will detect deception earlier than recreational players, reflected in an earlier increase in verbal and physical response accuracy on deceptive trials, higher discriminability scores, and an earlier reduction in bias toward judging actions to be genuine. Our final hypothesis is that high-skilled players will spend less time focused on peripheral sources of visual information, such as the head and feet, than recreational players, and will spend a greater proportion of time viewing areas aligned with centre of mass (i.e., abdomen and hip areas) as the action unfolds.

2. Method

2.1 Participants

A priori power analysis using G*Power (Faul et al., 2007) for the ANOVA within-between interaction, using a medium effect size (f = 0.25), power set at 0.80, and alpha at .05, yielded a recommended total sample size of 24 for four levels of the repeated measure and a sample size of 18 for seven levels of the repeated measure. Thirty-eight adult male rugby players participated in the present experiment. The high-skilled group comprised 19 participants (*M* age = 23.4 years, *SD* = 5.35), who engaged in 6.42 hours (*SD* = 1.82) of rugby specific activity per week and had a mean of 15.1 years (*SD* = 6.0) of competitive experience. All the high-skilled players were active competitors in the

Championship and National Leagues (tiers 2 to 4) and reported involvement in representative rugby, ranging from international to regional (county) experience. The recreational group comprised 19 participants (*M* age = 20.9, *SD* = 2.80) who played regular recreational rugby at a club or in intramural university competition. At the time of the study, they reported a weekly involvement in rugby-specific activity of 2.92 hours (*SD* = 1.87) and 7.97 years (*SD* = 4.12) of playing experience. The study was approved by the university research ethics committee and participants provided informed consent before taking part.

2.2 Test Stimuli

The task was a two-choice anticipation task, designed to simulate a one-vs-one tackle scenario in rugby. To create the test stimuli, we recruited two male highly skilled rugby union players who were aged 20 and 23 with 13 and 19 years of playing experience, respectively. The players were recommended by their coaches as they were deemed to possess advanced evasive footwork skills. To create smooth dynamic footage that was more representative of the competitive scenario than that recorded from a static video camera (den Hollander et al., 2016), a high-resolution action camera (Xiaomi Yi 4K, China) was mounted to a three-axis hand-held gimbal (FeiyuTech, WG2, China), which moved towards the attacking player as they approached. On each trial, the attacking player adopted a start position 18 m from the researcher who held the gimbal-mounted camera. The attacking player and researcher ran and walked directly toward each other, respectively, before the attacking player changed direction to evade the researcher by moving to their left or right. On genuine trials, players were instructed to perform a sharp “cut” change of direction. For deceptive trials, the players were instructed to execute a “sidestep” action to give the impression of changing direction to one side before going in the opposite direction.

Individual trials were analysed independently by the lead investigator and a volunteer with experience in similar research, based on the angle of approach, running speed and the technical execution of the action. The three highest-rated examples of each player changing direction to the left and right, with or without a deceptive sidestep, were chosen for the test film. The 24 unique video clips were edited to create seven times of occlusion relative to the first footfall after the initial (genuine or fake) reorientation (see Figure 1; Adobe Premiere Pro, v. 12.0, Adobe Inc., USA). The resultant 168 trials were presented in four blocks of 42 trials; each block contained clips from one player and block order was counterbalanced across participants. Individual trials were separated by a five-second inter-trial interval and trial order within each block was randomised with respect to action outcome (left, right), deception (deceptive, genuine) and time of occlusion (T1-T7).

** Figure 1 approximately here **

2.3 Instruments and Procedure

To record visual search behaviour, participants wore Sensomotor Instruments (SMI) eye-tracking glasses throughout the experiment. Search behaviours were recorded at a sampling rate of 60 Hz and the glasses were operated remotely (iView, SMI, Germany) with a three-point calibration at the beginning of each block of trials. Stimuli were presented on a large screen (4.05 m × 2.50 m) using a long throw data projector (Hitachi, CP8AW100N). The stimuli were viewed from a distance of 2.50 m. The vertical visual angle subtended by the players in the video at the point at which they changed direction was approximately 15 to 18 degrees. This was equivalent to the players changing direction approximately 5.9 m to 6.6 m from the participant. To record physical responses, the viewing platform contained two force plates (Bertec, USA) and was surrounded by 12 motion capture cameras (Vicon Bonita, Oxford Metrics, UK). Preliminary pilot work demonstrated a high correlation between peak horizontal force and maximum horizontal displacement of the centre of mass in individual responses. Moreover, the pilot showed strong similarities between the mediolateral location of the pelvis and the centre of mass. Accordingly, four reflective markers were attached to each participant's pelvis at the anterior and posterior iliac spines to collect motion capture data for the mediolateral movement from the physical responses at a sampling rate of 250 Hz. Before the first block of test trials, participants were shown 16 practice trials to familiarise them with the test design and response requirements. The familiarisation trials were different from those used in the test and included examples of genuine and deceptive actions to the left and right, occluded at T3 and T5.

On arrival, participants were given an opportunity to read the information sheet that had been sent to them prior to attending and the experimenter explained the task via a standardised instruction script. They were informed that their task was to watch a series of brief video clips and judge whether the player intended to take the ball to their left or right by moving as they would in order to intercept the player and make a "tackle". Participants were instructed to place one foot on each force plate prior to the start of each trial and all responses were generated from this position. During the trials, they were allowed to lift their feet to execute an interceptive movement. To encourage realistic responses, we instructed participants to respond as naturally as possible throughout the experiment. Accordingly, they were not required to make a physical response if the visual information presented was insufficient to prompt a natural response. After each video clip, participants were instructed to verbally judge the direction they believed the player intended to travel – regardless of any physical response they had made.

2.4 Data Analysis

For each time of occlusion, the proportions of correct and incorrect verbal responses on genuine and deceptive trials were used to calculate measures of discriminability (*d'*), and response bias (*c*). First, the proportion of correct responses on genuine trials ('hits') and incorrect responses to deceptive trials ('false alarms') were converted to z-values. To control for the possibility of infinite z-values, proportions of 0 and 1 were replaced with 1 - 1/2n, and 0 with 1/2n, where n is the number of trials in that condition (Hautus, 1995). To obtain *d'*, the z-values for false alarm responses on deceptive trails were subtracted from the z-values for correct responses on genuine trials. To calculate *c*, the sum of the z-scores were multiplied by -0.5.

Analysis of verbal response accuracy and physical response accuracy was conducted using arcsine transformations of the proportion of correct responses in each occlusion condition. To analyse overall verbal response accuracy, we conducted a 2 (expertise) × 2 (deception; genuine, deceptive) × 7 (time of occlusion) ANOVA, with deception and time of occlusion entered as repeated measures. To examine the influence of expertise on deception susceptibility (T1 to T4) and deception detection (T4 to T7) we entered the discriminability (*d'*) and response bias (*c*) data into separate Expertise × Time of Occlusion ANOVAs. We identified the two windows by visual inspection of changes in response accuracy and response bias across times of occlusion (Warren-West & Jackson, 2020). Susceptibility to deception was characterised by decreasing response accuracy across times of occlusion for deceptive actions and a strengthening of bias toward judging actions to be genuine. In contrast, detection of deception was characterised by increasing response accuracy across times of occlusion for deceptive actions and weakening of response bias. The inflection points for response accuracy and response bias were different for the two groups so we used the high-skilled group data to facilitate group comparisons across the same windows of occlusion. Accordingly, it should be noted that the ‘susceptibility to deception’ window extended to T5 in the recreational group.

To analyse physical responses, motion capture data were labelled and processed in Vicon Nexus (2.6.1. Oxford Metrics, UK) and examined in MATLAB (version R2017b) via an external user interface for physical responses. The interface highlighted the trials where a participant had made a mediolateral movement response greater than 5 cm of hip displacement; in line with the threshold suggested by Brault et al. (2012). To ensure that physical responses to the stimuli were being examined, responses only registered if the associated horizontal force was in excess of three standard deviations outside of the participant’s idle forces. During this analysis, the first response greater than 5 cm on each trial was recorded for physical response accuracy amplitude. As with the discriminability and bias analyses, physical response accuracy and amplitude data were divided into the ‘deception susceptibility’ (T1 to T4) and ‘deception detection’ (T4 to T7) windows. These were analysed using a 2 (expertise) × 4 (time of occlusion) ANOVA for each experimental condition. In addition, physical response frequency was recorded for each time of occlusion and analysed via a 2 (expertise) × 2 (deception; genuine, deceptive) × 7 (time of occlusion) ANOVA. Bonferroni contrast tests and pairwise comparisons were conducted to resolve significant effects and interactions, where appropriate.

Visual gaze behaviours were analysed using BeGaze software (SMI, Germany) to calculate the percentage of time that players spent fixated on the five areas of interest (AOI): the player’s head, chest, abdomen, hips, and legs. A fixation was classified as point-of-gaze maintained on an AOI for a minimum of 100 ms (Manor & Gordon, 2003). All trials occluded at T7 were examined to calculate percentages in three time intervals (-1200 ms to -800 ms, -800 ms to -400 ms, and -400 to 0 ms; see Navia et al., 2017; Savelsbergh et al., 2002). To analyse these data, percentage viewing times were entered into a 2 (expertise) × 3 (time interval) × 5 (fixation location) ANOVA.

For all analyses, alpha was set at .05 and partial eta squared (η_p^2) was used to indicate effect size (JASP statistics 10.2, University of Amsterdam, Netherlands). We applied the conservative Greenhouse-Geisser correction to the degrees of freedom in any tests in which the sphericity assumption was violated. In instances of multiple follow-up comparison tests, the Bonferroni correction was applied to alpha to control for familywise error.

3. Results

3.1 Verbal Response Accuracy – Omnibus

Analysis of verbal response accuracy across T1 to T7 revealed a medium to large effect for the interaction between expertise, deception, and time of occlusion, $F(4.13, 148.75) = 3.99$, $p = .004$, $\eta_p^2 = .10$. As can be seen in Figure 2, the main source of the three-way interaction was a larger expertise effect for deceptive trials than genuine trials, which was most evident in trials occluded at T5 and T6. Follow-up analysis for the three-way interaction revealed a non-significant Expertise × Time of Occlusion interaction for the genuine trials, $F(3.54, 127.52) = 1.71$, $p = .16$, $\eta_p^2 = .05$. For the deceptive trials, there was a significant Expertise × Time of Occlusion interaction, $F(4.03, 144.98) = 4.15$, $p = .003$, $\eta_p^2 = .10$. Pairwise comparisons for the deceptive trials revealed that there was a significant expertise effect for trials occluded at T5, $t(36) = 3.62$, $p < .001$, $d = 1.18$, and T6, $t(36) = 2.10$, $p = .04$, $d = 0.68$.

** Figure 2 approximately here **

3.2 Deception Susceptibility (T1 to T4)

3.2.1 Verbal Response Discriminability and Bias

The ability of high-skilled and recreational participants to discriminate between genuine and deceptive actions is illustrated in Figure 3 (panel A). Across T1 to T4, discriminability was very low. The Expertise × Time of Occlusion interaction approached significance, $F(2.87, 103.28) = 2.45$, $p = .07$, $\eta_p^2 = .06$, and follow-up pairwise comparisons showed that the effect of expertise was significant only at T2, $t(36) = 3.42$, $p = .002$, $d = 1.11$. As can be seen in Figure 3 (Panel A), discriminability increased from T1 to T4 in both groups because the proportion of correct responses in genuine trials increased more strongly than the proportion of incorrect responses in deceptive trials (i.e., false alarms). Separate contrast tests revealed that the significant linear relationship between discriminability and time of occlusion yielded the largest effect, Recreational: $F(1, 18) = 27.11$, $p < .001$, $\eta_p^2 = .60$; High-skilled: $F(1, 18) = 27.94$, $p < .001$, $\eta_p^2 = .61$.

Susceptibility to deception was also reflected in a large increase in response bias toward judging actions to be genuine from T1 to T4, $F(2.46, 88.43) = 8.92$, $p < .001$, $\eta_p^2 = .71$ (Figure 3, panel B), which in turn reflected the increase in correct responses in genuine trials and false alarm responses in deceptive trials across these points of occlusion. The change in response bias across T1 to T4 was similar in the two groups, reflected in a non-significant Expertise × Time of Occlusion interaction, $F(2.46, 88.43) = 2.35$, $p = .09$, $\eta_p^2 = .06$. Separate contrast tests revealed that the largest effect was for the linear relationship between response bias and time of occlusion, Recreational: $F(1, 18) = 101.58$, $p < .001$, $\eta_p^2 = .85$; High-skilled: $F(1, 18) = 68.30$, $p < .001$, $\eta_p^2 = .79$.

** Figure 3 approximately here**

3.2.2 Physical Response Accuracy and Amplitude

Of the responses made, the high-skilled group (*M* = 55.50%, *SD* = 34.86) were more accurate than the recreational group (*M* = 47.43%, *SD* = 34.70), *F*(1, 19) = 10.77, *p* = .004, η_p^2 = .36 (Figure 4). From T1 to T4, the percentage of correct responses increased on genuine trials and decreased on deceptive trials, which resulted in a large effect for the Deception × Time of Occlusion interaction, *F*(3, 57) = 13.20, *p* < .001, η_p^2 = .41. Separate contrast tests revealed that the largest effect was for the positive linear relationship with time of occlusion in the genuine trials, *F*(1, 30) = 43.30, *p* < .001, η_p^2 = .59, and was for the negative linear relationship with time of occlusion in the deceptive trials, *F*(1, 21) = 14.03, *p* = .001, η_p^2 = .40.

Across T1 to T4, mean displacement increased toward the correct side in genuine trials and increased toward the incorrect side in deceptive trials. This was reflected in a large effect for the Deception × Time of Occlusion interaction, *F*(2.21, 41.91) = 17.50, *p* < .001, η_p^2 = .48. Separate contrast tests most strongly supported a positive linear relationship with time of occlusion in the genuine trials, *F*(1, 27) = 47.23, *p* < .001, η_p^2 = .64, and a negative linear relationship with time of occlusion in the deceptive trials, *F*(1, 20) = 19.44, *p* = .001, η_p^2 = .49. Consistent with the response accuracy data, mean displacement was greater for the high-skilled group (*M* = 1.40 cm, *SD* = 9.97) than the recreational group (*M* = -0.11 cm, *SD* = 8.25), *F*(1, 19) = 8.37, *p* = .01, η_p^2 = .31. The Expertise × Time of occlusion interaction was non-significant, *F*(2.35, 44.68) = 0.18, *p* = 0.87, η_p^2 = .01. The expertise effect was consistent across deceptive and genuine actions, reflected by a non-significant interaction between expertise and deception *F*(1, 19) = 0.01, *p* = .91, η_p^2 = .001, and a non-significant three-way interaction between expertise, deception and time of occlusion, *F*(2.21, 41.91) = 0.84, p = .45, η_p^2 = .04.

** Figure 4 approximately here**

** Figure 5 approximately here**

3.3 Deception Detection (T4 to T7)

3.3.1 Verbal Response Discriminability and Bias

The ability of both groups to discriminate between genuine and deceptive actions improved markedly from T4 to T7, *F*(2.44, 87.97) = 350.73, p < .001, η_p^2 = .91. A contrast test showed strong support for a linear increase across times of occlusion, *F*(1, 36) = 2133.03, p < .001, $\eta_p^2 = .98$, with pairwise comparisons showing significant increases from each time of occlusion to the next (all *p*s < .001). Descriptively, the expertise effect was greatest at T5 (see Figure 3, panel A), which was mostly driven by differences in response accuracy between the two groups when judging deceptive actions (see Figure 2). Specifically, accuracy of the high-skilled group improved to near chance level, whereas, the recreational group recorded its lowest proportion of correct responses to deceptive actions. The analysis revealed a significant expertise by time of occlusion interaction, *F*(2.44, 87.97) = 4.68, p = .01, $\eta_p^2 = .12$. Follow up comparisons at each time of occlusion showed that the expertise effect was non-significant at T4, *t*(36) = 0.75, p = .46, d = 0.24, and T7, *t*(36) = 1.83, p = .08, d = 0.60, and was significant at T5, *t*(36) = 3.62, p < .001, d = 1.17, and T6, *t*(36) = 2.30, p = .03, d = 0.75.

Analysis of response bias toward judging actions to be genuine revealed a significant interaction between expertise and time of occlusion, *F*(3, 108) = 5.28, p = .002, η_p^2 = .13. Follow up comparisons at each time of occlusion revealed that the expertise effect was non-significant at T4, *t*(36) = 0.38, p = .71, d = 0.12, and T7, *t*(36)

= 0.45, p = .66, d = 0.15, and was significant at T5, $t(36) = 3.39$, p = .002, d = 1.10, and T6, $t(36) = 2.30$, p = .03, d = 0.75

3.3.2 Physical Response Accuracy and Amplitude

The high-skilled group (M = 74.82%, SD = 30.28) made a greater proportion of correct responses than the recreational group (M = 59.72%, SD = 33.14), $F(1, 36) = 26.47$, $p < .001$, $\eta_p^2 = .42$. The proportion of correct responses was far higher for genuine actions than deceptive actions, $F(1, 36) = 246.06$, $p < .001$, $\eta_p^2 = .87$. Descriptively, the medium effect size associated with the Expertise × Deception interaction reflected a stronger expertise effect for deceptive actions than genuine actions, $F(1, 36) = 3.90$, $p = .06$, $\eta_p^2 = .10$ (see Figure 4). Follow-up analysis confirmed a very large expertise effect for the deceptive trials, $F(1, 36) = 51.68$, $p < .001$, $\eta_p^2 = .59$, and a smaller effect of expertise for the genuine trials, $F(1, 36) = 3.52$, $p = .07$, $\eta_p^2 = .09$.

In regard to the amplitude of physical responses in the deception detection window, the high-skilled players (M = 10.66cm, SD = 14.94) made larger lateral responses in the correct (+ve) direction than the recreational players (M = 5.08cm, SD = 7.18), $F(1, 36) = 7.30$, $p = .01$, $\eta_p^2 = .17$. Analysis revealed a medium-large effect for the Expertise × Deception × Time of Occlusion interaction, $F(2.06, 74.15) = 5.35$, $p = .01$, $\eta_p^2 = .13$ (see Figure 5). Follow-up analysis revealed that, for genuine trials the expertise effect was non-significant, $F(1, 36) = 2.42$, $p = 0.13$, $\eta_p^2 = 0.06$, as was the interaction between expertise and time of occlusion, $F(3, 108) = 1.83$, $p = 0.15$, $\eta_p^2 = 0.05$. For the deceptive trials, there was a significant Expertise × Time of Occlusion interaction, $F(1.48, 53.30) = 5.37$, $p = 0.01$, $\eta_p^2 = 0.13$. Pairwise comparisons showed that there was a significant effect of expertise at T6, $t(36) = 4.79$, $p < .001$, d = 1.55, and T7, $t(36) = 3.07$, p = .004, d = 1.00, but not at T4 (p = .53) and T5 (p = 0.32).

3.4 Response Frequency

As more of the action was revealed to participants, response frequency increased (see Figure 6), $F(2.91, 104.86) = 223.36$, $p < .001$, $\eta_p^2 = .86$. Contrast tests revealed the effect was largest for a linear relationship with time of occlusion, $F(1, 36) = 449.23$, $p < .001$, $\eta_p^2 = .93$. Pairwise comparisons showed a significant increase in response frequency at each time of occlusion from T1 to T5 (all *p*s < .001), then non-significant increases from T5 to T6 ($p = .51$) and T6 to T7 ($p = 1.00$). The pattern across time of occlusion was highly consistent across high-skilled ($M = 7.10$, $SD = 4.05$) and recreational players ($M = 7.10$, $SD = 4.04$), as evidenced by a non-significant effect of expertise ($p = 1$) and the expertise by time of occlusion interaction, $F(2, 36) = 0.46$, $p = .70$, $\eta_p^2 = .01$. Participants responded to a higher proportion of genuine trials than deceptive trials, $F(1,36) = 51.56$, $p < .001$, $\eta_p^2 = .59$. Descriptively, this difference was greatest on trials occluded at T4 and T5 (see Figure 6) and was less prominent in other times of occlusion. This was born out by a significant interaction between deception and time of occlusion, $F(4.13, 148.69) = 2.62$, $p = .04$, $\eta_p^2 = .07$, and follow-up pairwise comparisons, which showed the largest effects of deception were observed in trials occluded at T4 ($\eta_p^2 = .49$) and T5 ($\eta_p^2 = .30$) and the smallest were at those occluded at T1 ($\eta_p^2 = .15$), T2 ($\eta_p^2 = .08$), and T7 ($\eta_p^2 = .10$).

** Figure 6 approximately here**

3.5 Visual Gaze Behaviours

Analysis of the percentage of time recreational and high-skilled players spent viewing the five AOIs revealed a large effect for the Gaze location × Time window interaction, $F(4.62, 147.90) = 7.50$, $p < .001$, $\eta_p^2 = .19$. Contrast tests showed a linear increase in gaze toward the opponent’s chest, $F(1, 33) = 24.36$, $p < .001$, $\eta_p^2 = .43$, and abdomen,

$F(1, 33) = 4.38$, $p = .04$, $\eta_p^2 = .12$, as the action unfolded. Conversely, there was a linear decrease in gaze toward the opponent's legs across the time windows, $F(1, 33) = 11.80$, $p = .002$, $\eta_p^2 = .26$. Other decreases were observed in the quadratic effects of time window for gaze toward the opponent's head (decrease then level), $F(1, 33) = 24.36$, $p < .001$, $\eta_p^2 = .43$, and hips (level then decrease), $F(1, 33) = 10.65$, $p = .003$, $\eta_p^2 = .24$.

There was a medium effect for the Expertise × Gaze location interaction, $F(2.05, 65.65) = 2.65$, $p = .08$, $\eta_p^2 = .08$. Planned analysis of individual AOIs revealed that high-skilled players spent a significantly greater percentage of time viewing the opponent's abdomen (*M* = 32.78%, *SD* = 15.82) than did recreational players (*M* = 20.94%, *SD* = 12.57), $t(32) = 2.41$, $p = .01$, $d = 0.82$. Conversely, recreational players spent more time observing the opponent's head (*M* = 30.42%, *SD* = 27.36) than did high-skilled players (*M* = 15.24%, *SD* = 19.45), $t(32) = 1.86$, $p = .04$, $d = 0.64$. No significant differences were found at the chest, hips or legs.

** Figure 7 approximately here**

4. Discussion

In their review of research on deception in duelling sports, Jackson and Cañal-Bruland (2019) highlighted that few researchers have examined the time window in which performers become deceived. They argued that this has led to impoverished understanding of how performers become deceived relative to the substantial progress made in understanding expert detection of deception (Güldenpenning et al., 2017). Following recent work to address this issue (Warren-West & Jackson, 2020), the purpose of the present study was to examine expertise effects in the discriminability of genuine and deceptive actions through measurement of physical and verbal responses to videos presented on a large-screen. A comprehensive analysis of participants' verbal and physical responses, as well as derived measures of discriminability and response bias, revealed mixed evidence regarding susceptibility to deception and clear evidence that high-skilled players were better able to detect deception than recreational players. While we make a conceptual distinction between the susceptibility and deception windows in our study, the windows are data-driven so are dependent on the performance of each group.

In the deception susceptibility window, we hypothesised that high-skilled players would be less susceptible to deception than their recreational counterparts (Warren-West & Jackson, 2020). Analysis of the verbal response data showed that high-skilled and recreational rugby players were equally susceptible to deception (Figure 2), and this was particularly evident in the discriminability and response bias data for the T1 to T4 window (Figure 3). In contrast, we found an expertise effect in our analysis of the physical response data. This revealed that high-skilled players made a higher proportion of correct responses than recreational participants, particularly to deceptive actions (Figure 4), and responded more effectively (greater displacement), particularly to genuine actions occluded at T3 and T4 (Figure 5). This suggests that physical response accuracy may be a more sensitive measure of deception than verbal responses in this test environment and might be more appropriate for detecting smaller expertise effects associated with initial susceptibility to deception. For example, Schutz et al. (2020) demonstrated that whole-body kinematics were a more sensitive measure of gaze deception (head fakes), than button press (reaction time) responses, when judging basketball passes displayed on a large projection screen. Indeed, the broad pattern of physical response accuracy data in the present study (Figure 4) is very similar to that reported in a study that used button press responses to video clips shown on a computer screen (Warren-West & Jackson, 2020). This suggests that higher-skilled players are indeed less susceptible to deception; however, the experimental context and task design might influence the way in which it is expressed. It is also important to acknowledge that statistical power is affected by the number of trials that contribute to the measures we used. We maximised the number of trials in each cell within the constraints imposed by the different times of occlusion, keeping in mind the possibility of boredom or fatigue effects. As a result, the total number of trials was 168 but calculations of ‘hits’ and ‘false alarms’ were each calculated from responses to 12 trials in each time of occlusion. This in turn results in a relatively coarse estimation of the Gaussian distribution probability values.

Verbal judgements during the deception detection window support the findings of previous deception research (Brault et al., 2012; Jackson et al., 2018; Mori & Shimada, 2013; Warren-West & Jackson, 2020) and provide further evidence that high-skilled players are better at detecting deception. More specifically, high-skilled players were able to verbally discriminate between genuine and deceptive actions earlier than recreational players as the action unfolded. This was most evident from T4 to T5 and was accompanied by an earlier plateau and reduction in perceptual bias as the high-skilled performers became less likely to perceive the initial change in direction to be genuine (see Figure 3, panel B). These advantages for the high-skilled group were almost entirely driven by fewer ‘false alarms’ (incorrect responses to deceptive actions) relative to the recreational group (Figure 2). These results align with the findings from recent studies of football stepovers and rugby sidesteps, which showed an earlier weakening of perceptual bias in more skilled players (Jackson et al., 2018; Warren-West & Jackson, 2020).

For movement responses, as the later information was made available, the high-skilled participants made a greater percentage of correct responses to deceptive trials, than the recreational participants (see Figure 4). Despite similar response frequencies between groups at each time of occlusion, the high-skilled players were able to act upon reliable information available later in the deceptive action sequence; whereas, the recreational players were more likely to commit to a response based on earlier deceptive cues. Accordingly, Displacement was almost identical between skill groups on deceptive trials from T1 to T5, followed by large difference at T6 and T7, as the high-skilled group produced greater responses. High-skilled players were also more effective at responding to genuine trials, with progressively larger displacement across T1 to T7 (See Figure 5).

Considering physical response accuracy alongside verbal response accuracy we can conclude that earlier detection of deception facilitates superior physical responses of high-skilled players to deceptive actions. A comparison of the figures shows that as more of the action is shown, deception is detected and incorrect responses to previous cues are inhibited, allowing a correct response to be initiated. In an immersive perception and action experiment, Brault et al. (2012) aimed to quantify the degree to which rugby players are fooled by deceptive action using full-body responses to a virtual player. Similarly, to the present study, their lower skilled group (novices) made a greater percentage of incorrect responses, of greater magnitude, than experts to deceptive actions. They argued that this was a result of novices being more sensitive to deceptive signals and experts more attuned to honest signals. Additionally, their high-skilled performers waited longer to initiate responses to deceptive actions. Research has previously suggested that expert performers wait longer to respond due to greater action capabilities (Fajen et al., 2008). Affordance-based control (Fajen, 2005) suggests that greater understanding of the scenario, coupled with an understanding of their own ability, allows experts to extract as much information as they can in line with the temporal constraints of the task. In turn, they can respond to reliable global and local cues available later in the action sequence (Diaz et al., 2012), while a novice performer may be forced to act on less reliable information presented earlier (e.g. Brault et al, 2012). Using much larger responses than the present study, Dicks et al. (2011), examined the relationship between football goalkeepers' action-capabilities (reactive agility) and penalty kick response accuracy. Their study showed that goalkeepers with greater action capabilities were superior at anticipating the outcome of both deceptive and genuine penalty kicks. The authors concluded that the greater perception of agile goalkeepers was driven by being able to attend advanced signals as the action unfolded. Similar effects were shown in return of serve in tennis, with some players capable of utilising visual information after the point of racket-ball contact (Triolet et al., 2013). Interestingly, our findings do not support affordance-based control in the typical sense of suggesting that experts wait longer to respond, as the response frequencies for high-skilled and recreational players were similar at each time of occlusion. Instead, our results suggest that when presented with a deceptive action – or when the outcome of an action is perceived as ambiguous – experts will wait longer to decide how they will respond, making them less like to "bite" on the fake change of direction in rugby sidesteps. In practical terms, the high-skilled groups' ability to supress responses based on initial information would increase the probability of performing a successful tackle. In contrast, the false alarm responses (displacement in the wrong direction) of the recreational players would reduce the likelihood of tackle completion (Wheeler et al., 2010).

Researchers have suggested that expert performers employ more effective visual search strategies to extract crucial information when making anticipatory judgements (Piras et al., 2014). Such studies proposed that the reason expert rugby players can detect deception more successfully than less-skilled players is that they are more attuned to “honest” signals associated with centre of mass and able to ignore deceptive signals such as the head and legs (Brault et al., 2012). Our analysis of visual gaze behaviours supports this interpretation as the high-skilled group spent the greatest proportion of time viewing the opponent’s abdomen – an “honest” landmark (Brault et al., 2010, 2012) – whereas, the recreational group spent the greatest proportion of time viewing the opponent’s head. Moreover, as the action unfolded both groups showed a general shift in visual gaze away from the legs to areas of the body aligned more closely with centre of mass (Abdomen and Chest). We are not implying, however, that all information used to detect deceptive intent was located at the point of focus as there is evidence that elite perceptual skill involves processing information from multiple sources (Huys et al., 2008; Jackson et al., 2018; Loffing & Hagemann, 2014). In addition, gaze research has revealed that performers are able to pool information from foveal and peripheral fields of view (Schorer et al., 2013) and by using a stable gaze strategy, it has been suggested that covert attention can move around the field of vision to monitor multiple cues simultaneously. In our study, the abdomen may have been used as a stable visual anchor due to its central location on the body; supporting the idea that high-skilled performance are more effective at identifying the optimal anchor point for processing information (Alder et al., 2014; Mann et al., 2019; Wu et al., 2013). By inference, signals used to deceive an opponent likely involve the manipulation of multiple sources to create misleading relational information (Kuhn & Findlay, 2010; Kuhn & Martinez, 2012).

Many considerations were made during the conceptualisation of the present study to create an accurate representation of the effect of deceptive actions in a one-vs-one rugby tackle situation. Most notably, we used a semi-immersive CAREN lab environment, which allowed us to present large-screen test footage, to manipulate temporal occlusions precisely, and to record precise time-synchronised physical response measures alongside visual search behaviour and verbal judgment data. This allowed us to identify commonalities and differences between the verbal and full-body response data. Notably, the full-body responses were more consistent with a recent study that examined susceptibility to deception using computer button-press responses (Warren-West & Jackson, 2020). Nonetheless, research has shown that natural responses can increase anticipatory performance and the expert advantage in interceptive tasks (Mann et al., 2010). We acknowledge that the experimental context and task design can influence the effects of deception and the expert advantage. The design of the present study affords “natural” physical responses along with verbal responses. Given the nature of the experimental environment, verbal responses may have been a less sensitive measure of deception as they were further removed from the behaviour associated with life-size stimuli. Therefore, we propose that for designs using a realistic environment, physical/natural responses should be favoured. Likewise, in computer-based designs, physical responses (full-body adjustments) are likely to feel unnatural and key-press responses should be preferred. The two designs, however, are complimentary, with the advantage of computer-based environments being that they are more accessible and typically afford a greater level of control over stimuli presentation and manipulation. These reasons, coupled with the similar findings they have produced for deception detection (e.g., Brault et al., 2012; Jackson et al., 2006; Mori & Shimada, 2013), and now deception susceptibility, makes computer-based designs an invaluable tool for this line of research. Another important consideration was the type of participant. We recruited only high-skilled (professional and semi-professional) and recreational rugby players to take part. This allowed us to compare the effect of deceptive actions on different levels of performers, all of whom understood the nature of the task, the demands of the rugby tackle scenario, and the response requirements. In turn, this increases the potential practical significance of the findings relative to studies that compare expert and novice performers.

5. Conclusion

The present study is the first to examine initial *susceptibility* to deception using full body physical responses to large screen video stimuli. In so doing, we were able to plot expertise effects across the full time window of deceptive actions from initial susceptibility to subsequent detection of deception. The findings from both response formats showed that both recreational and skilled players were susceptible to deception, and analysis of physical responses showed that high-skilled players were less susceptible to deception than recreational players (Warren-West & Jackson, 2020). Data from both response modes confirmed that experts subsequently detected that an action was deceptive earlier in the action sequence. This study helps establish the full time window of deception, which will allow researchers to specify and distinguish between the kinematic information that *causes* deception and that which is used to *detect* deception (cf. Brault et al., 2012). The degree to which players are attuned to this information likely determines their ability to respond effectively to challenging sport environments in which disguise and deception are commonplace.

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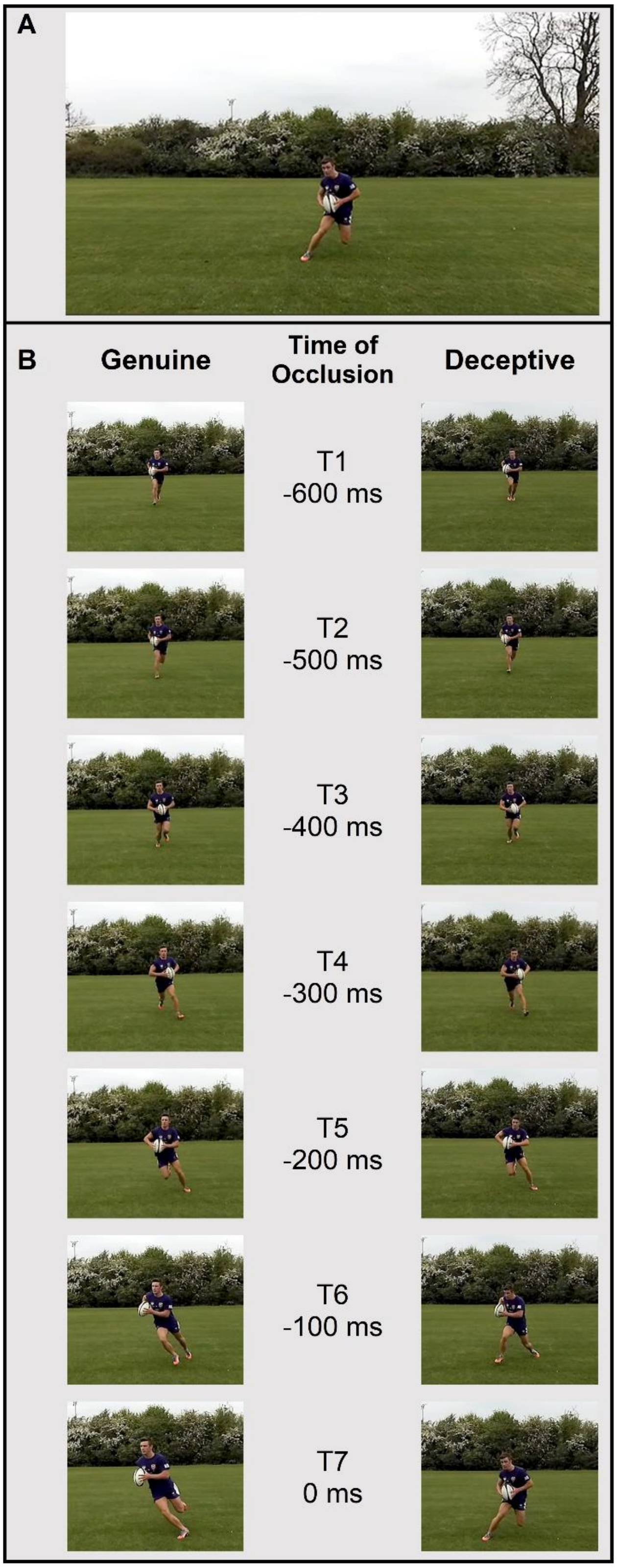

1

2 Figure 1. A Representation of the seven times of occlusion. The images depict the final

3 frame at each time of occlusion.

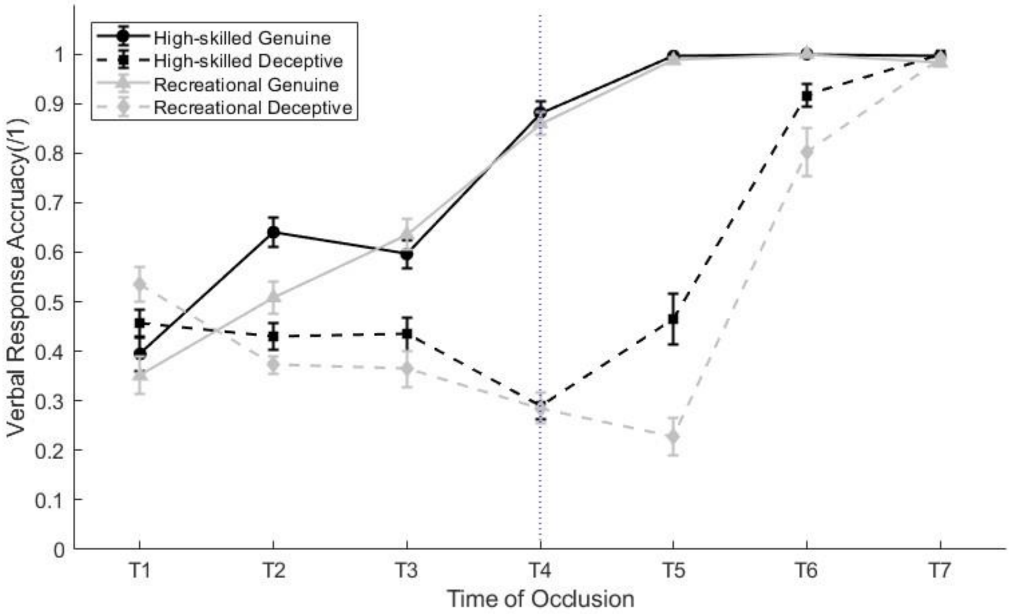

Figure 2. Mean verbal response accuracy (± *SE*) for genuine and deceptive actions at each time of occlusion. T1 to T4 represents the deception susceptibility window, and T4 to T7 represents the deception detection window.

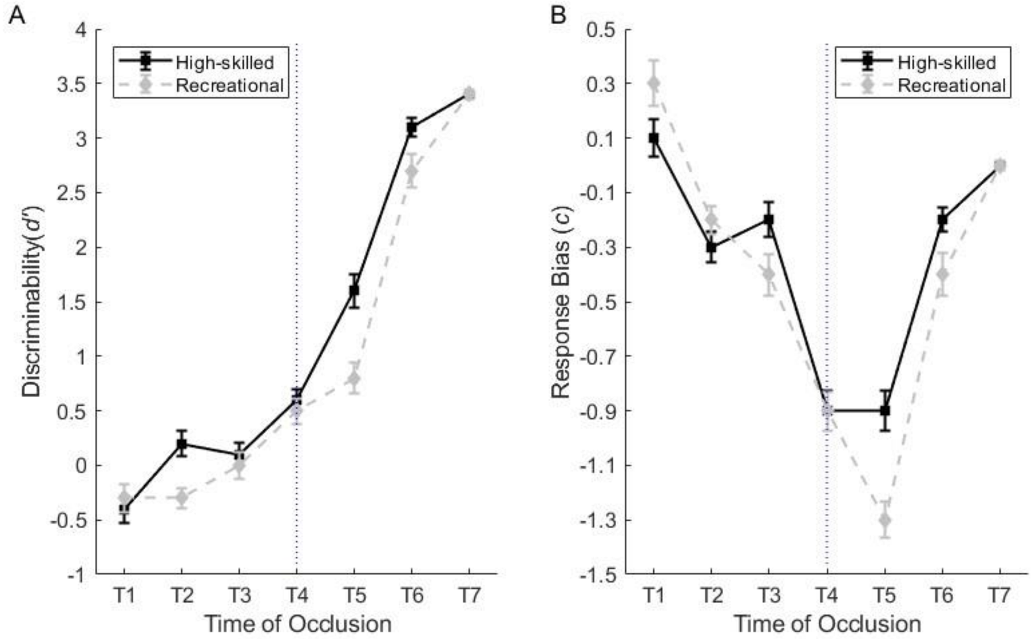

Figure 3. Mean discriminability (*d'* ± *SE*) for the high-skilled and recreational groups at each time of occlusion (Panel A), and mean response bias (*c* ± *SE*) for the high-skilled and recreational players at each time of occlusion (Panel B).

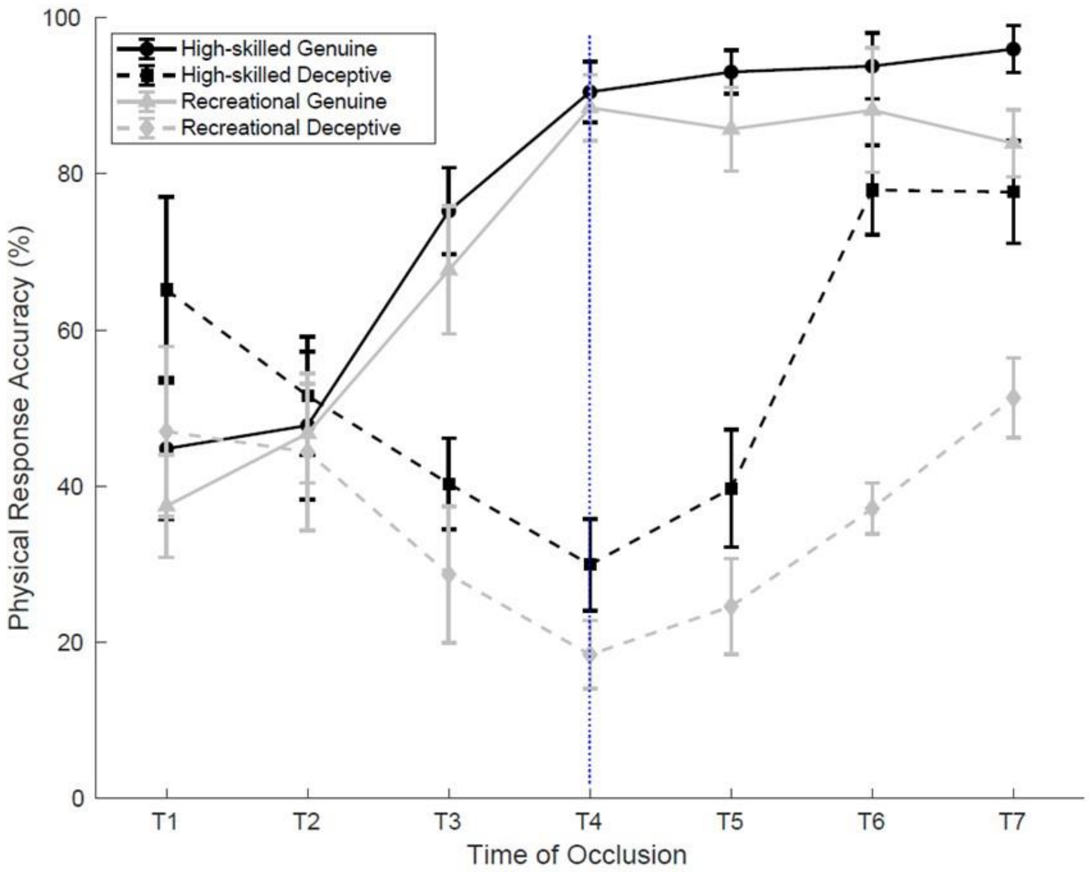

Figure 4. Mean physical response accuracy (± *SE*) at each time of occlusion.

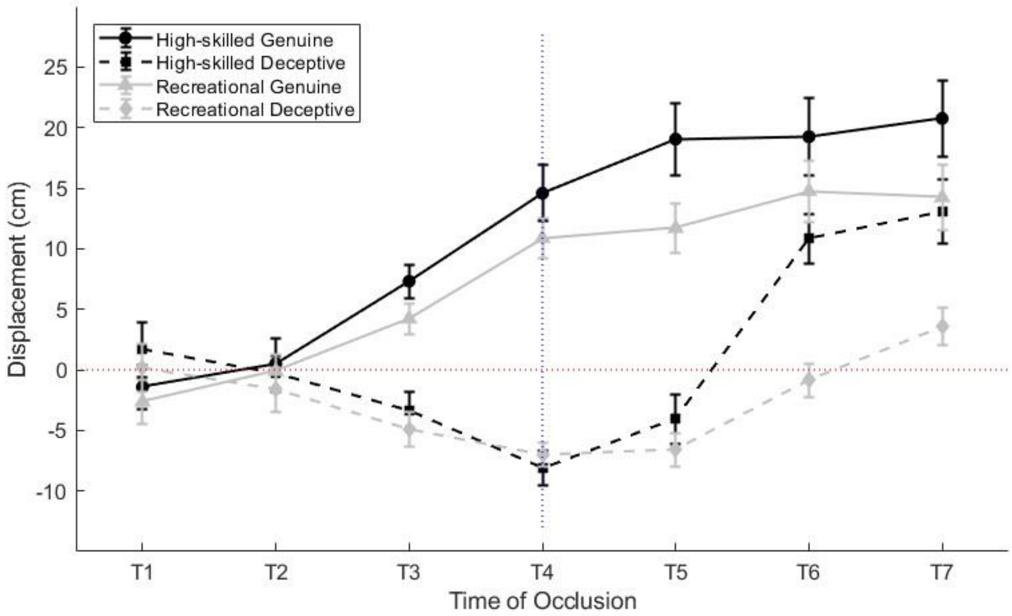

Figure 5. Mean response amplitude (± *SE*) at each time of occlusion. Positive values indicate displacement in the correct direction.

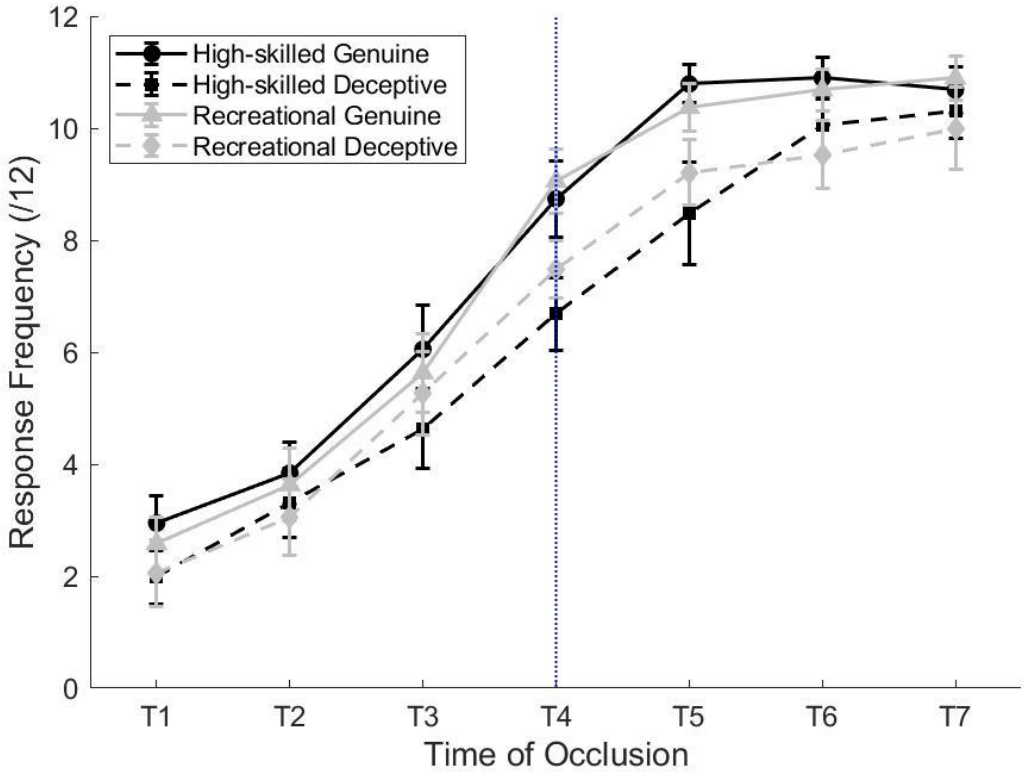

Figure 6. Mean number of physical responses (± *SE*) at each time of occlusion.

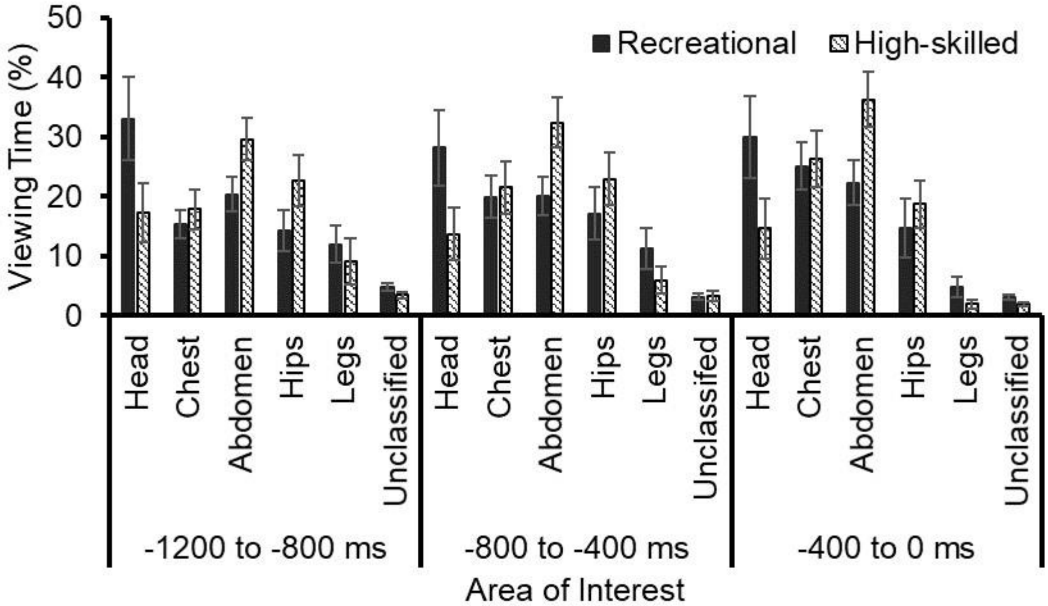

Figure 7. The mean percentage of time (± SE) spent by the high-skilled and recreational groups viewing each area of interest in each of the three time intervals