

Running Head: ANTICIPATION SKILL AND BLURRING

Sensitivity to fine-grained and coarse visual information: The effect of blurring on
anticipation skill

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Abstract

We examined skilled tennis players' ability to perceive fine and coarse information by assessing their ability to predict serve direction under three levels of visual blur. A temporal occlusion design was used in which skilled players viewed serves struck by two players that were occluded at one of four points relative to ball-racquet impact (-320ms, -160ms, 0ms, +160ms) and shown with one of three levels of blur (no blur, 20% blur, 40% blur). Using a within-task criterion to establish good and poor anticipators, the results revealed a significant interaction between anticipation skill and level of blur. Anticipation skill was significantly disrupted in the '20% blur' condition; however, judgment accuracy of both groups then improved in the '40% blur' condition while confidence in judgments declined. We conclude that there is evidence for processing of coarse configural information but that anticipation skill in this task was primarily driven by perception of fine-grained information.

Keywords: Perception, Visual Cues, Expertise.

Sensitivity to fine-grained and coarse visual information: The effect of blurring on anticipation skill

Interactive sports involve attempts by one performer to judge the intentions of his or her opponent. In many fast, reactive sports analysis of the time constraints for responding indicate that a strategy of waiting for unambiguous visual information (e.g., the flight of a tennis ball or a badminton shuttle) is likely to be ineffective as the sole means of governing one's responses, at least at the highest level of competition (Abernethy, 1991). Instead, in some cases it appears necessary and in all cases is potentially advantageous to be able to predict an opponent's actions in advance. There is now considerable evidence across a range of sports that skilled performers are more sensitive or better attuned to early visual information than are their lesser-skilled counterparts (e.g., Abernethy, 1990; Mann, Williams, Ward, & Janelle, 2007; Müller, Abernethy, & Farrow, 2006; Williams, Hodges, North, & Barton, 2006).

Researchers have sought to identify the spatial and temporal characteristics of information underlying anticipation skill using a range of techniques and both observational and experimental paradigms. Most commonly, the temporal occlusion paradigm has been used, often in combination with measures such as verbal reports (either retrospective or 'in-event' think aloud protocols) or analysis of eye movement during the task of interest (Farrow, Abernethy, & Jackson, 2005; Goulet, Bard, & Fleury, 1989; Isaacs & Finch, 1981; Williams, Ward, Knowles, & Smeeton, 2002). In addition, researchers have spatially occluded or removed potential sources of information in order to make inferences about the information underpinning skilled perceptual judgments (Jackson & Mogan, 2007). The nature of the visual stimuli has also been manipulated, most notably through the use of 'point-light' displays in which

only the movements of key joints are seen in the form of white dots or strips of light against a darkened background (Johanssen, 1973). In general, researchers using this technique have found that while performance is somewhat degraded under point-light conditions the expert advantage is retained, a finding that is consistent with experts being attuned to biological motion rather than more 'surface' characteristics of the display (Abernethy & Zawi, 2007; Abernethy, Gill, Parks, & Packer, 2001; Ward, Williams, & Bennett, 2002; c.f., Shim, Carlton, Chow, & Chae, 2005).

While research into anticipation skill has improved our understanding of the loci of important sources of information we still know very little about whether anticipation skill involves the perception of specific features of the display or whether it instead relies upon the processing of configural relationships, that is, the relative motion between two or more features. There is evidence using point-light displays of walkers that processing of global configural information supports judgments about biological motion (Bertenthal & Pinto, 1994). In face recognition, there is evidence for processing of both featural and configural information but the latter is generally considered to play a more important role. For example, face recognition is disrupted when participants view inverted images of faces, a manipulation that disrupts the configural arrangement of features (e.g., nose, eyes, mouth), even if the images are edited such that the individual features remain in the correct orientation (Valentine, 1988). There is also evidence that having participants describe a face in detail impairs subsequent recognition of that face (Schooler & Engstler-Schooler, 1990). It is argued that this 'verbal overshadowing' effect occurs because the act of describing the face orients the participant's attention towards processing of local featural information rather than global configural information (Macrae & Lewis, 2002).

In the domain of sport, the limited research thus far indicates that anticipation skill might similarly rely at least in part on the processing of configural relations between different features of the display. At one level, it seems clear that in many instances individual sources of visual information will become more meaningful when presented in relation to some other information source. Certainly this would seem to be so when perceiving the relative position of team-mates and opponents in team sports (Williams et al., 2006). In the realm of individual sports, Jackson and Mogan (2007) found that skilled tennis players were able to predict serve direction when only the ball toss and server's head were visible. While it is possible that either the isolated movement of the server's head or trajectory of the ball toss facilitated judgments, processing of the position of the ball *relative to* the server's head may well be more meaningful in the context of tennis serves. The importance of individual features will likely depend on the nature of the task. For example, Müller et al (2007) compared the ability of different levels of cricket batsmen to judge the type and length of 'delivery' from advance visual information. When viewing spin bowlers, who use movement of the wrist and hand to impart spin and vary both the flight and bounce characteristics of the ball, high-skilled batsmen were able to predict ball type above chance level when viewing only the bowling hand. By contrast, when viewing a swing bowler, high-skilled batsmen were unable to judge ball type above chance when viewing only isolated features but could do so when certain combinations of features were present.

One way to examine the relative importance of fine-grained movement of specific features of the performer and more coarsely defined configural information is to compromise the quality of featural information available to observers. For example, Thomas and Jordan (2002) examined the ability of participants to perceive speech

from facial movement when the face of the speaker was shown under different levels of blur. They found that while speech recognition was generally impaired under more blurred conditions, participants were still able to identify speech sounds above chance even in the most blurred condition when featural information was impossible to perceive. Thomas and Jordan concluded that speech recognition relies partly upon the processing of coarse configural relations between different regions of the face rather than solely on processing of fine features of mouth movement. Blurring has also been used to investigate interceptive actions in sport (Mann, Ho, De Souza, Watson, & Taylor, 2007) and was used by Kuhlmann and Lappe (2006) in a series of experiments investigating the perception of human actions. They found that action identification from movies was less impaired by blur than identification from single frames. They also found that identification was better when viewing still-frame sequences of 3 frames (the first, middle, and last frame of a 23-frame sequence) than when viewing a single static frame. The authors concluded that both global form and global motion information could be used to compensate for the loss of local information in the blurred conditions.

In the present study, we sought to test the hypothesis that anticipation skill in tennis relies at least in part on the perception of configural information contained within the movement of the server. To test this hypothesis we examined skilled tennis players' ability to judge the direction of serves viewed under different levels of blur, using a within-task criterion to classify performers as having either good or poor anticipation skill (Savelsbergh, van der Kamp, Williams, & Ward, 2002). Consistent with findings from the study of visual speech perception and evidence indicating the importance of individual features, we predicted that the addition of blur would lead to lower judgment accuracy. Consistent with the view that the expert advantage is

supported at least in part by the perception of configural information, we further predicted that good anticipators would maintain their advantage over poor anticipators under blurred conditions.

In addition to assessing performance, we sought to assess performers' awareness of the information upon which they based their judgments. In accordance with higher-order thought theory, our use of confidence ratings was based on the premise that awareness should be reflected in meta-cognitive thoughts about the judgments being made (Rosenthal, 2000). Confidence ratings and more specifically their relationship with performance (or lack thereof) have been used as a means of providing evidence for implicit learning (e.g., Dienes, Altmann, Kwan, & Goode, 1995) and for assessing awareness in the perceptual-motor domain (Jackson & Mogan, 2007; Jackson, Warren, & Abernethy, 2006; Masters, van der Kamp, & Jackson, 2007; Poulter, Jackson, Wann, & Berry, 2005). In terms of our present interest in featural and configural information, we predicted that confidence would decrease with the addition of blur, reflecting the increasing difficulty participants would have in perceiving fine featural information. We made an additional, tentative prediction that confidence and performance would become dissociated under blurred conditions. This was based on evidence from verbal reports in which skilled tennis players primarily referred to specific features rather than configural relations (e.g., Jackson & Mogan, 2007). It follows that if featural information is degraded by blurring, players will be less confident in their judgments. If performance is maintained this would result in a dissociation between confidence and performance.

Method

Participants

A total of 32 participants (29 men, 3 women) completed the study. They had a mean age of 25.0 years ($SD = 6.1$) and a mean of 13.1 years ($SD = 4.8$) competitive playing experience. Participants were currently competing in club regional competitions ($n = 15$), International Tennis Federation satellite tournaments ($n = 9$), or Association of Tennis Professionals' Challenger ($n = 6$), or Grand Prix ($n = 2$) events. All participants gave informed written consent prior to commencement of the study, which received clearance from the Human Research Ethics Committee of the University of Hong Kong.

Task Design and Construction of Test Stimuli

The task was a two-choice prediction task in which participants aimed to judge the direction of tennis serves from video footage occluded at four different points in the serve sequence and shown with three levels of blur. The test was comprised of a total of 96 video clips depicting the serve action of two right-handed male players serving the ball to the left or right side of the 'deuce' service box. The serves were filmed using a digital video camera set at a height of 1.6 m and positioned so as to create a viewing perspective equivalent to that which a receiver would have when preparing to receive serve on court. A large number of serves were originally filmed from which a total of eight serves (the two most accurate, legal serves to the left and right for each player) were selected for editing and inclusion in the anticipation test. Using Pinnacle Studio video editing software (version 9.0), the eight serves were edited to create four occlusion conditions relative to the final frame before the ball made contact with the racquet: t1 (-320ms), t2 (-160ms), t3 (0ms) and t4 (+160ms). The special effects module in the Pinnacle editing software was then used to add 20% and 40% blur in both the horizontal and vertical dimensions in order to create the three levels of blur. In this application, the level of blur is expressed as a

percentage, therefore does not correspond directly to the number of cycles per field-width described by Thomas and Jordan (2002) or a refractive index (Mann et al., 2007). A visual representation of the final frames associated with the different points of occlusion and blur conditions is presented in Figure 1.

****FIGURE 1 ABOUT HERE****

The order of the video clips in the test film was randomized with respect to server, level of blur, and occlusion condition. Each video clip lasted approximately 3.0 s and an inter-trial interval of 5 seconds was used to enable participants to register their judgment and express how confident they were, on a 5-point scale (1 = complete guessing, 5 = complete certainty).

Design and Procedure

We employed a 2 (Anticipation skill: good, poor) x 3 (Blur: 0%, 20%, 40%) x 4 (Occlusion condition: t1, t2, t3, t4) mixed-model design. To classify participants' anticipation skill we used a within-task criterion, conducting a median split based upon participants' mean performance when viewing the non-blurred video across occlusion conditions t1 to t3 (i.e., those in which ball flight information was not present). The good anticipators had a mean accuracy of 64.3% across the three pre-contact occlusion conditions when viewing the non-blurred serve sequences. The poor anticipators had a mean accuracy of 42.2% in the same conditions. After obtaining background information, we explained the nature of the task to participants who were then shown eight video clips in order to familiarise them with both the time constraints for responding and the different blur conditions. The practice trials consisted of two repetitions of four serves from a different player to those used in the test trials. They were made up of four serves with no blur, two serves with 20% blur and two serves with 40% blur. The test trials were then presented in three blocks of 32

serve separated by a rest period of approximately 1 minute. The practice and test trials were presented on a Dell 17" flat screen monitor, viewed from a distance of approximately 1.1 m so that the image of the server subtended a visual angle that was equivalent to that which would be experienced in the 'live' setting (approximately 4.1 degrees depending on the height and precise positioning of the server and the returning player). After viewing each trial, participants made a verbal response regarding the direction of the serve then rated their confidence in this judgment, each of which were recorded by the experimenter.

A logical distinction can be made between test conditions assessing participants' ability to use advance information and conditions in which ball-flight information indicating the direction of the serve is present. Consequently, separate analyses were conducted for the pre-contact (t1, t2, t3) and post-contact (t4) occlusion conditions. The performance data for t1 to t3 were first subjected to an arcsine transformation then entered into a 2 (anticipation skill) x 3 (blur) x 3 (occlusion) analysis of variance (ANOVA) with blur and occlusion entered as repeated measures. Planned repeated contrasts were conducted for the effects of blur and occlusion in order to compare performance at adjacent levels. The performance data at t4 were also transformed and subjected to a 2 (anticipation skill) x 3 (blur) ANOVA, with blur entered as repeated measure. The confidence data were similarly subjected to a 2 x 3 x 3 ANOVA for pre-contact data and a separate 2 x 3 ANOVA for post-contact data. In both cases, we report the univariate output, and have applied the Greenhouse-Geisser adjustment to the degrees of freedom where necessary to adjust for violations of the sphericity assumption. Effect size is indicated by partial eta squared (η_p^2) and alpha was set at .05 for all tests. Where appropriate, we have reported the transformed mean and standard error values to accompany output from the statistical tests.

Results

Performance

The performance data are illustrated in Figure 2. Analysis of the pre-contact performance data (t1, t2, t3) revealed significant main effects of anticipation skill ($F(1, 27) = 17.73, p = .00, \eta_p^2 = .40$), blur ($F(2, 54) = 4.85, p = .01, \eta_p^2 = .15$), and occlusion ($F(2, 54) = 6.94, p = .00, \eta_p^2 = .33$). As expected, overall performance was better for good anticipators ($M = 0.60, SE = 0.02$) than for poor anticipators ($M = 0.50, SE = 0.02$). Consistent with previous tests of anticipation skill in tennis, the primary source of the occlusion main effect was information pick up from t2 ($M = 0.51, SE = 0.02$) to t3 ($M = 0.61, SE = 0.03$), that is, the period just before ball-racket contact ($p = .00, \eta_p^2 = .27$) with no significant difference evident between performance at t1 and t2 ($p = .42$). The repeated contrasts for the blur main effect indicated that performance declined significantly from the '0% blur' ($M = 0.58, SE = 0.02$) to the '20% blur' condition ($M = 0.50, SE = 0.02; p = .00, \eta_p^2 = .30$) but was significantly better in the '40% blur' condition ($M = 0.56, SE = 0.02$) than in the '20% blur' condition ($p = .03, \eta_p^2 = .16$).

The main effect of blur was superseded by a significant interaction with anticipation skill ($F(2, 54) = 18.63, p = .00, \eta_p^2 = .41$), indicating that the addition of blur had different effects on good and poor anticipators. The repeated contrasts revealed that the primary source of the interaction was the change in performance from the '0% blur' to '20% blur' condition ($p = .00, \eta_p^2 = .59$) rather than from '20% blur' to '40% blur' ($p = .44$). As can be seen in the lower graph in Figure 2, the performance of good anticipators declined substantially from the '0% blur' to the '20% blur' condition whereas the performance of poor anticipators improved slightly with the addition of '20% blur'. Both groups then showed similar improvements from

‘20% blur’ to ‘40% blur’. The interactions between occlusion and anticipation skill, occlusion and blur, and the three-way interaction between anticipation skill, occlusion and blur were non-significant.

Analysis of the post-contact performance data revealed a significant main effect of blur ($F(2, 54) = 62.05, p = .00, \eta_p^2 = .70$) and non-significant effects for anticipation skill ($p = .40$) and the anticipation skill by blur interaction ($p = .83$). Repeated contrasts for the effect of blur revealed that performance was significantly better in the non-blurred condition ($M = 1.54, SE = 0.02$) than the 20% blur condition ($M = 1.34, SE = 0.06; p = .01, \eta_p^2 = .21$), which in turn was better than in the 40% blur condition ($M = 0.85, SE = 0.05; p = .00, \eta_p^2 = .69$).

****INSERT FIGURE 2 ABOUT HERE****

Confidence

The confidence rating data are illustrated in Figure 3. The results of the ANOVA for the pre-contact confidence ratings revealed significant main effects of blur ($F(2, 54) = 120.65, p = .00, \eta_p^2 = .82$) and of occlusion ($F(2, 54) = 122.00, p = .00, \eta_p^2 = .82$). Repeated contrasts revealed a decline in judgment confidence both from ‘0% blur’ to ‘20% blur’ ($p = .00, \eta_p^2 = .67$) and from ‘20% blur’ to ‘40% blur’ ($p = .00, \eta_p^2 = .79$), even though judgment accuracy improved significantly in the latter. Repeated contrasts for the occlusion main effect indicated that participants expressed increasing confidence in their judgments both from t1 to t2 ($p = .00, \eta_p^2 = .61$) and from t2 to t3 ($p = .00, \eta_p^2 = .79$). The main effect of anticipation skill was non-significant ($p = .64$), as were the two-way and three-way interactions.

The ANOVA for the post-contact confidence data revealed a main effect of blur ($F(1.41, 38.02) = 71.21, p = .00, \eta_p^2 = .73$), a non-significant main effect of anticipation skill ($p = .54$), and a non-significant interaction between the two ($p =$

.33). Repeated contrasts again revealed that participants became significantly less confident about their judgments from '0% blur' to '20% blur' ($p = .00$, $\eta_p^2 = .38$) and from '20% blur' to '40% blur' ($p = .00$, $\eta_p^2 = .77$).

****INSERT FIGURE 3 ABOUT HERE****

Discussion

The purpose of the study was to examine the effect of blurring the display on the ability to make perceptual judgments from 'advance' visual information. In so doing, we sought to make inferences about the nature of information being used, distinguishing between fine-grained featural information and more coarse configural information. At the outset, we should emphasize that we used a response that effectively 'decoupled' perception from action so, as with all studies using verbal or written responses, it is possible that the results would be different when such coupling is maintained. However, recent work examining this issue is encouraging, indicating a good degree of consistency between lab-based studies using video presentations and field-based studies using occlusion goggles and coupled responses (Farrow, Abernethy, & Jackson, 2005).

As predicted, blurring significantly impaired the ability to make judgments, indicating the importance of fine-grained featural information; however, the effect of blurring on performance was non-linear and interacted with anticipation skill. We predicted that good anticipators would maintain an advantage over poor anticipators in the blurred displays but found no indication that this was the case. Indeed, adding 20% blur to the stimuli was most detrimental to the good anticipators whereas the performance of poor anticipators improved slightly from the 0% blur condition to the 20% blur condition. Furthermore, judgment performance of both groups was significantly better in the 40% blur condition than in the 20% blur condition.

In interpreting these data, it is informative to consider the effect of blurring on how visual information affects auditory speech recognition. Thomas and Jordan (2002) found that incongruent visual speech continued to influence perceived speech sounds when featural information had been degraded by blurring. As such, they concluded that perception of configural relations also conveyed speech information. In the present study, the fact that anticipatory judgments improved from the 20% blur to 40% blur condition similarly suggests that both good and poor anticipators (all of whom were experienced tennis players) were able to perceive coarse configural information to support their judgments when featural information was degraded. At the same time, the performance of good anticipators was still well below that attained in the non-blurred condition, indicating that anticipation skill, like visual speech recognition, is primarily supported by information carried at higher spatial frequencies. Consistent with this interpretation, Abernethy and Zawi (2007, Experiment 2) found that expert badminton players were able to use the isolated point-light movement of either the racquet or the lower body to judge stroke direction whereas recreational players could not.

It is important to acknowledge that blurring does not entirely separate the contribution of fine-grained featural and coarse configural information. However, previous studies in which researchers have manipulated the spatial frequency information of an image indicate that coarse information is processed by low spatial frequency channels whereas fine information is processed by high spatial frequency channels (De Valois & De Valois, 1988; cited in Thomas & Jordan, 2002). The effect of blurring, therefore, is to degrade the fine-grained information while coarse information is, by definition, less affected. In terms of the distinction between featural and configural information, it remains possible that observers process fine-grained,

local relations between different features. For example, a cricketer might perceive the configural relations between a spin bowler's wrist, palm and fingers that would be impaired by blurring. However, in the same way that the interrelationships between facial features are maintained when viewing blurred facial movements (Thomas & Jordan), the more gross configural relations remained evident when viewing the blurred tennis serve sequences. For example, it was still possible to perceive the movement of the ball in the 40% blur condition.

In further considering the decline in performance from the '0% blur' to '20% blur' condition and subsequent improvement from '20% blur' to the '40% blur' condition we should also acknowledge the possibility that participants adopted different strategies in response to the different levels of blur. In particular, the lower level of performance of good anticipators in the '20% blur' condition might reflect their continued attempts to identify featural information, a strategy they discarded in the '40% blur' trials. Compensation strategies of this sort have been observed in a judgment tasks requiring participants to identify human actions when viewing blurred movie clips (Kuhlmann & Lappe, 2006). It would be useful in future research to use verbal reports and analysis of eye movements to help shed light on the different strategies adopted when the visual stimuli are manipulated in this way.

Evidence from 3D motion analysis of a professional male tennis player indicated that the most indicative sources of information for judging serve direction were the motion of the racquet as it swings up to strike the ball, shoulder rotation just prior to ball-racquet impact, the trajectory of the ball toss, and ball position at the moment of impact (e.g., Moreno & Oña, 1998; Moreno, Oña, & Martínez, 2002).. Studies using occlusion paradigms, verbal reports, and analysis of visual gaze have generally supported this finding and point to the critical time period for three of these

sources being immediately before ball-racquet contact. In the current experiment, this information was present at occlusion point t3 but not at t2 or t1 and consistent with previous research the source of the occlusion main effect was the improvement in performance from t2 to t3, the final 160 ms before ball-racquet impact. The speed with which the racquet moves towards the ball together with the subtle differences in angle of approach and orientation of the racquet head would seem to necessitate that such information needs to be viewed at high spatial frequency.

With respect to the confidence data, the most significant finding was the dissociation between changes in confidence and changes in performance from the 20% blur to the 40% blur condition. Confidence about judgments decreased while predictive performance improved significantly. If one accepts the theoretical premise that awareness of the information upon which judgments are based will be reflected in the confidence attached to such judgments, this suggests that performers' awareness was largely restricted to fine-grained featural information. Had participants been aware of their ability to use coarser configural information, confidence should not have declined from the 20% blur to the 40% blur condition, and arguably should have reflected the improvement in performance. Indeed, the pattern of decreasing confidence associated with judgments in the 0%, 20%, and 40% blur conditions was almost linear (lower graph, Figure 3), as was the increase in level of blur.

The pattern of confidence ratings across the different occlusion conditions generally reflected changes in performance. In the pre-contact occlusion conditions confidence increased more from t2 to t3 than from t1 to t2, reflecting the significant performance improvement from t2 to t3. However, it should be noted that confidence associated with judgments at t2 was significantly greater than at t1 even though performance remained at the same level. There are at least two possible explanations

for this. First, confidence ratings may have partly reflected participants' awareness that they have been given more information (by virtue of a later occlusion point) on which to base their judgments. Second, participants may have believed they were picking up indicative information in the additional 160ms from t1 to t2 that was in fact redundant with respect to the servers they viewed. In the first instance, this raises the question of how 'pure' a measure of awareness are confidence ratings. Dienes (2004) critically assessed the assumptions underlying use of subjective measures of awareness, and acknowledged that confidence ratings were potentially susceptible to bias. Indeed, he acknowledged that potential biases exist in both the formation and expression of the second-order thought (e.g., when participants translate their subjective feeling of confidence onto a 5-point scale). Perhaps more relevant to the present experiment, Dienes outlined ways in which a second-order thought (in this case the expression of confidence) may itself be biased by a yet higher-order thought regarding the state of confidence. Thus, awareness that one has seen more of the serve action or has viewed it with less blur may influence the expression of confidence in addition to the information one is conscious of perceiving.

In conclusion, the present study provides evidence that anticipation skill when responding to tennis serves is primarily based on the processing of fine featural information. At the same time, the data suggest that skilled tennis players (whether good or poor anticipators) are able to perceive coarse configural relations to some degree, though the processing of the latter did not discriminate good and poor anticipators. While the effect of blurring on interceptive skills has recently been examined in cricket (Mann et al., 2007), the present study is the first to attempt to use blur as a means of assessing the nature of information perceived in anticipation skill. As such, our conclusions are somewhat tentative at this stage. There is a clear need

for additional cross-sectional research using a range of sports skills so that we can determine the robustness and generalisability of the present findings.

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Figure Captions

Figure 1. An illustration of the last video frame shown in each of the four occlusion conditions (t1, t2, t3, t4) for each level of blur (0%, 20%, 40%). The actual test stimuli were shown in colour in avi format.

Figure 2. Mean arcsine transformed judgement accuracy scores for good and poor anticipators in the four occlusion conditions (top graph) and under the three levels of blur (bottom graph). Bars represent standard errors of the associated mean values.

Figure 3. Mean confidence ratings for good and poor anticipators in the four occlusion conditions (top graph) and under the three levels of blur (bottom graph). Bars represent standard errors of the associated mean values.

FIGURE 1

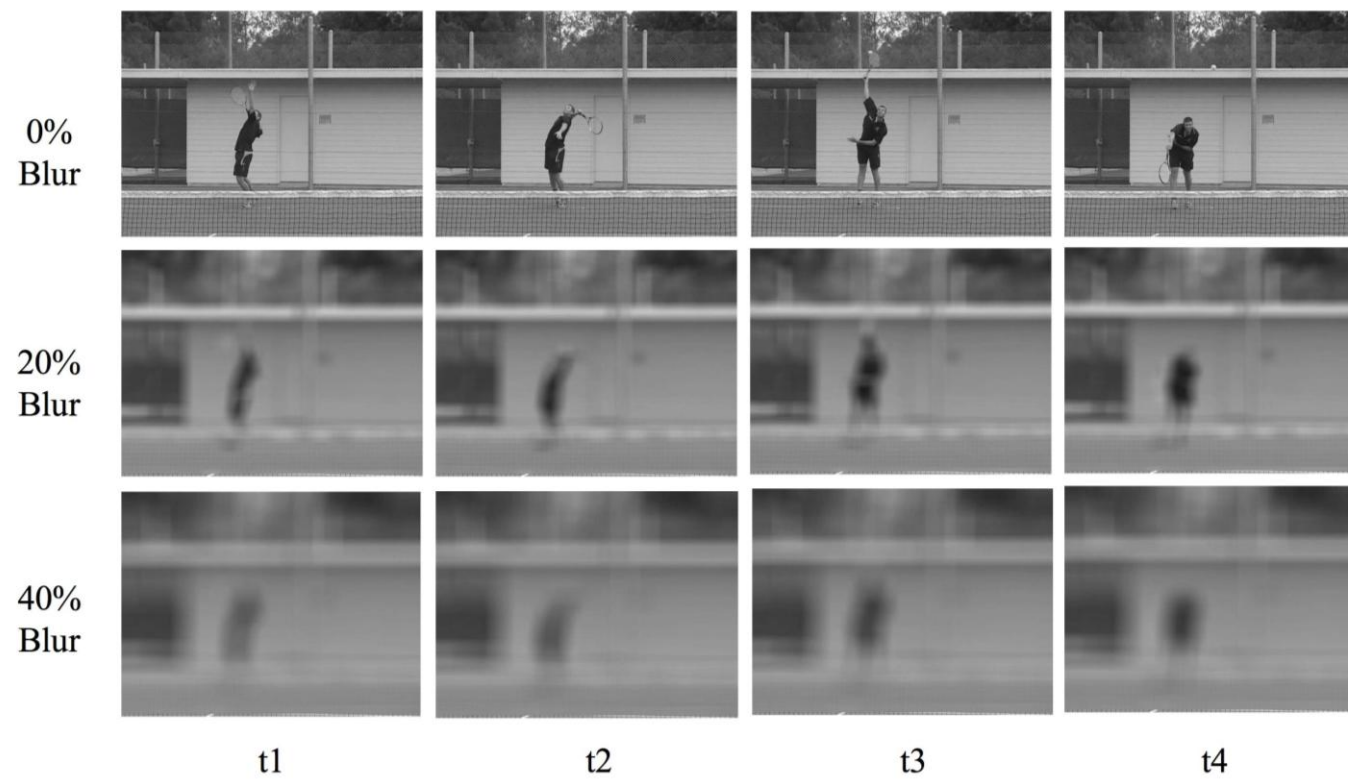


FIGURE 2

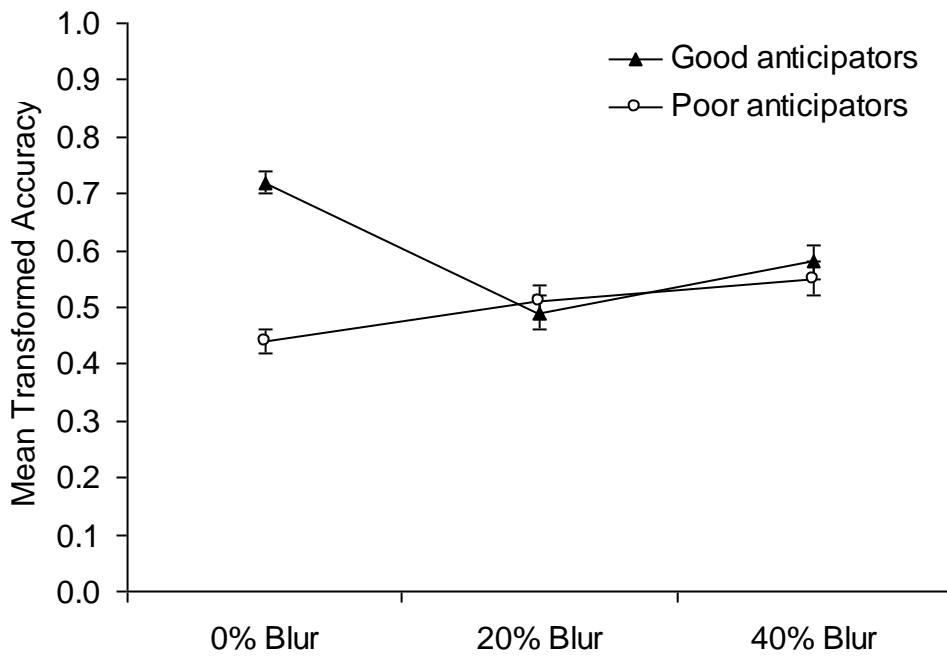
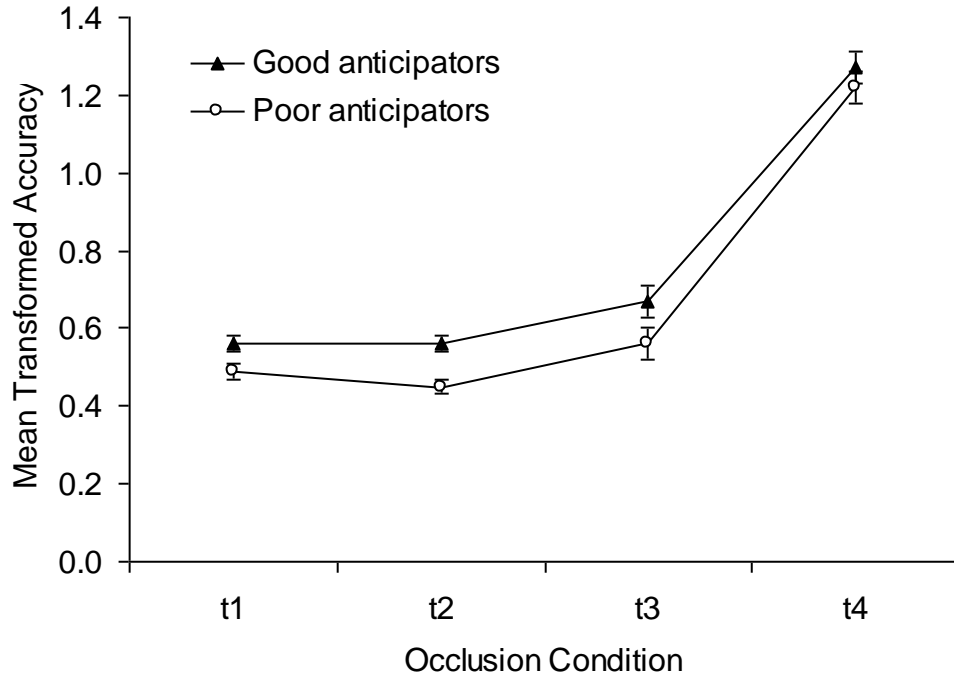


FIGURE 3

