Advance Visual Information, Awareness, and Anticipation Skill

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ABSTRACT. The authors examined 13 skilled, 13 recreational, and 11 novice players’ awareness of the advance visual information that they used to judge tennis serve direction. Participants viewed video clips of serve actions under 5 conditions of spatial occlusion. The authors assessed participants’ awareness by comparing the different groups’ confidence associated with correct and incorrect judgments and by conducting a postexperiment free-recall test. The results indicated that information from the ball toss and the arm + racquet region underpinned players’ anticipation skill and that greater expertise was accompanied by increasing awareness of the information on which judgments were based. The authors discuss the implications of the present results for researchers’ use of confidence ratings to assess awareness in perceptual-judgment tasks.

Keywords: confidence, expertise, visual cues

One of the characteristics of expertise in many reactive skills is the ability to use advance visual information from an opponent’s movement patterns to anticipate behavioral events (Abernethy, 2001; Williams, Davids, & Williams, 1999). Analysis of the time constraints in skills such as judging the direction of a tennis, badminton, or squash shot; striking a cricket ball or baseball; and making a penalty save in soccer highlights the importance of making decisions before unambiguous ball-flight information becomes available. For example, Abernethy (1991) calculated that when returning tennis serves traveling at 40–45 m/s, a receiver has 500–600 ms to judge the direction and speed of the ball and organize and execute the movements needed to make a successful return. On the basis of that and similar observations in other reactive skills (e.g., Glencross & Cibich, 1977; Howarth, Walsh, Abernethy, & Snyder, 1984; McLeod, 1987; Muller, Abernethy, & Farrow, 2006), researchers have sought to establish whether and to what extent anticipation skill differentiates performers of varying skill levels.

Investigators have commonly used the progressive temporal occlusion paradigm to address the aforementioned questions. In that paradigm, experimenters show participants video clips of the task in question that they have edited to reveal varying amounts of information relative to a key point such as the moment at which the projectile is struck (whereupon unambiguous ball-flight information becomes available). After each clip, participants are required to make a judgment from the behavior that they observed. The results of many such studies have revealed that the ability to make critical judgments from advance visual information reliably discriminates performers of different skill groupings. That finding has proved robust across many sports, including badminton (Abernethy, 1988, 1991; Abernethy & Russell, 1987), cricket (Abernethy & Russell, 1984), soccer (Williams, 2000), tennis (Goulet, Bard, & Fleury, 1989; Jones & Miles, 1978; Shim, Chow, Carlton, & Chae, 2005; Singer, Caeraugh, Chen, Steinberg, & Frehlich, 1996), and squash (Abernethy, 1990b; Abernethy, Gill, Parks, & Packer, 2001; Howarth et al., 1984).

In tennis, for example, Jones and Miles (1978) found that expert coaches were better than novice players at predicting serve direction from video clips of serves that were occluded 42 ms before racquet–ball contact. When the video clips included 336 ms of postcontact ball-flight information, coaches and novices did not differ in their levels of accuracy. Isaacs and Finch (1983) found a similar advantage for intermediate-level players over novices in

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reporting the lateral displacement of a serve; that advantage was most pronounced for video that was occluded just before racquet–ball contact. Since then, Farrow and Abernethy (2003) and Farrow, Abernethy, and Jackson (2005) have reported similar findings in both laboratory and field tests, and they include judgments about the type of serve (Goulet et al., 1989) and events from open-court play (Buckolz, Prapavesis, & Fairs, 1988; Shim et al., 2005; Williams, Ward, Knowles, & Smeeton, 2002).

Although there is a significant body of literature documenting the expert advantage in anticipation skill, in most cases the nature of the visual information that skilled players use is not very well understood (Pollick, Fidopiastis, & Braden, 2001). To determine candidate sources of information, researchers have used a number of techniques, including three-dimensional motion analysis, analysis of the observer’s visual search patterns, and the selective occlusion of specific regions of the display. For example, Moreno and Oña (1998; Moreno, Oña, & Martínez, 2002) conducted biomechanical analyses of a professional tennis player, and they identified the trajectory of the racquet as it moved to strike the ball, shoulder rotation just before ball–racquet impact, the trajectory of the ball toss, and the ball position at the moment of impact as critical for judging serve direction. Thus far, researchers have used biomechanical analyses only sparingly in that context, and most of them have instead focused on the observer who is engaged in the anticipation process. The relative merits of analyzing visual search patterns and using the spatial occlusion paradigm continue to be the subject of discussion (Abernethy, 2001; Williams et al., 1999). However, one may consider the two techniques complementary insofar as spatial occlusion or manipulation paradigms can help researchers confirm the importance of information sources specified by analysis of visual gaze.

Consequently, one of our aims in the present study was to identify the specific sources of information receivers use to anticipate serve direction in tennis. To that end, we used a variant of the spatial occlusion technique in which we cloned the background to remove selected parts of the digitized image (see Poulter, Jackson, Wann, & Berry, 2005). Because of the number of studies in which investigators have used the tennis serve to analyze anticipation skill, it is surprising that they have yet to use spatial or event occlusion to confirm the importance of cues indicated by visual search data. For example, Goulet et al. (1989) analyzed expert and novice tennis players’ sequences of eye movements as they watched video sequences of different types of serve. The researchers found that as the server moved to strike the ball up to the point of ball–racquet contact, the experts fixated more on the server’s racquet and arm area, whereas the novices continued to fixate on the ball. Singer et al. (1998) explored tennis players’ visual search behaviors on court as they faced serves from other skilled players. Singer et al. found that the best male and female players demonstrated 100% pursuit tracking of the ball during the ball-toss phase and had the highest number of fixations on the arm–racquet–shoulder region during the ritual phase before the serve action commenced.

Investigators have previously demonstrated the importance of the arm and racquet regions in studies in which they used the spatial occlusion paradigm to assess anticipation skill in other racquet sports. For example, Abernethy (1988) found that expert badminton players had significantly increased radial error when they judged the landing position of shots in which the racquet was occluded and a further increase in error when both the arm and the racquet regions were occluded. Occlusion of the arm and the racquet similarly led to increased depth error in the judgments of expert squash players (Abernethy, 1990a). Investigators have done less work on manipulating images to influence players’ judgment accuracy. However, Pollick et al. (2001) found that exaggerating the spatial characteristics of different types of tennis serve (flat, top-spin, slice) in comparison with a prototypical grand average of all three serves affected how well the observers could identify them. On the top-spin serve, for which the spatial characteristics of the serve motion and the ball toss deviated most from the grand average, exaggerating the difference by a factor of 1.5 or 2.0 enhanced observers’ identification accuracy. Exaggerating the spatial characteristics of the slice serve, for which the serve motion and ball toss differed least from the grand average, had little effect on identification accuracy.

In the present study, we predicted (Hypothesis 1) that participants’ skill level would have a significant effect on their predictions of serve direction when they viewed normal, unoccluded serve sequences that ended on the last frame before the ball was struck. In line with research indicating the importance of the ball toss, arm, and racquet regions (Moreno et al., 2002; Pollick et al., 2001; Singer et al., 1998), we further predicted (Hypothesis 2) that skilled participants’ performance in comparison with that in the unoccluded condition would be most significantly impaired when we removed each of those cue sources. Consistent with research highlighting the discriminatory qualities of the ball toss, we finally predicted that (Hypothesis 3) the skilled groups’ performance would be significantly above chance level when we occluded the server’s whole body so that only his head and the ball toss remained visible.

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With only judgment accuracy data, researchers cannot determine whether performers are aware of the information on which they base their judgments. Because of investigators’ growing interest in the merits of less directed or implicit perceptual training interventions, they clearly need to understand better the explicit–implicit nature of anticipation skill and the associated perceptual judgments (Farrow & Abernethy, 2002; Jackson, 2003; Jackson & Farrow, 2005; Masters, van der Kamp & Jackson, 2007; Williams et al., 2002). Verbal reports provide one means of assessing awareness, and researchers have used them extensively to assess explicit knowledge in studies of implicit motor learning (Masters, 1992; Maxwell,
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of landing position than were intermediate players, and the that expert players were less confident in their judgments on a scale from 0 to 100. Tenenbaum and colleagues reported that when viewing a range of different shots, they were viewing a range of different shots. After participants made responses on a scaled diagram of a tennis court, they were asked to rate how confident they were in their prediction on a scale from 0 to 100. Tenenbaum and colleagues reported that expert players were less confident in their judgments of landing position than were intermediate players, and the latter players were, in turn, less confident than were novices.

Conversely, when ball-flight information became available, experts were significantly more confident in their judgments than were novices and intermediates. It is unclear whether that result was indicative of genuine underconfidence on the part of experts or was a reflection of the different expectations of each group. Because those investigators used a continuous variable (radial error) to assess performance, it is possible that the expert group had higher expectations about how accurate they would be and were less confident of achieving that level of accuracy until ball-flight information became available. In the present study, we used a discrete measure of accuracy to control for that possibility. All participants thus had the same reference criterion for success, which further allowed us to compare the confidence associated with correct and incorrect responses.

Jackson, Warren, and Abernethy (2006) recently, recorded rugby union players' confidence when they studied the players' susceptibility to deceptive movement. Overall, they found no significant difference between the confidence ratings of expert and novice players. However, both groups were more confident on trials containing deceptive movement than on normal trials. Whereas the expert group performed at the same level under both conditions, novices performed significantly worse on the deception trials. Jackson et al. suggested that the exaggerated movements in the deception trials led to explicit judgments, with the poorer level of performance of the novices indicating that they were more commonly (and consciously) fooled by the deceptive movement. The evidence from deception is important because an actor's ability to present effective exaggerated movements implies that he or she has knowledge of the information observers' use in making their judgments. If anticipation skill were largely based on implicit processes, then performers would presumably not have explicit knowledge of how to deceive their opponent.

Consequently, our second purpose in the present study was to assess participants' awareness of the information on which they based their decisions. We therefore asked participants to rate how confident they were in each of their judgments, and we used a postexperiment free-recall test of the sources of information that they used in making judgments. We predicted (Hypothesis 4) that their ability to judge serve direction would be accompanied by awareness, as reflected in a higher confidence for correct than for incorrect judgments (Tunney & Shanks, 2003). Second, in line with predictions regarding different occlusion conditions, we predicted that (Hypothesis 5) the skilled group would refer to information from the serving arm, the racquet, and the ball toss to a greater extent than would the less skilled groups (Goulet et al., 1989; Singer et al., 1998).

Method

Participants

Participants were 37 university students from the United Kingdom (n = 18) and from Hong Kong (n = 19). We
divided them into three groups on the basis of their previous competitive experience and current playing level. The skilled players \((n = 13)\) had a mean age of 20.4 years \((SD = 1.9 \text{ years})\) and a mean of 9.6 years \((SD = 2.5 \text{ years})\) of tennis-playing experience, and they reported that they had played in a mean of 283.8 competitive matches. At the time of the study, they were competing for their university’s first team or in county- or regional-level competitions. The recreational players \((n = 13)\) had a mean age of 20.7 years \((SD = 1.7 \text{ years})\) and a mean of 8.9 years \((SD = 2.4 \text{ years})\) of tennis-playing experience, but they had played in a mean of only 7.2 competitive matches. They were not playing competitive tennis at the time of the study. The novice players \((n = 11)\) had a mean age of 21.6 years \((SD = 3.1 \text{ years})\) and a mean of 0.6 years \((SD = 0.6 \text{ years})\) of tennis-playing experience, and they had never played in organized tennis competitions. Thirty-five of the participants played tennis right-handed, and 2 played left-handed. We obtained ethical clearance from the respective university ethics committees, and all participants gave informed consent before participating in the study.

**Task Design**

The task enabled us to examine the participants’ ability to predict the direction of tennis serves by viewing video footage that we had temporally occluded on the last frame before racquet–ball contact. That was the final frame before ball-flight information became available, and we chose it to include all possible information sources that might support anticipation skill. We used a 3 × 5 mixed-factor design, with skill level and occlusion condition serving as the between- and within-participant factors, respectively.

**Test stimuli.** We created the test stimuli from digital video footage of a right-handed professional tennis coach serving down the center of the court (center), into the body of the receiver (body), or wide toward the tramlines. We filmed the serves with a digital video camera (Panasonic Model NVMX8-B) that we set at a height of 1.6 m to create a vertical visual angle of 8.2° (that angle is slightly larger than the 4.3° angle that a 1.8-m-tall server subtends on an actual tennis court). The results of anticipation tests across a variety of tasks have proved consistent across a range of visual angles, so we expected that presentation of the stimuli at slightly larger viewing angles than in the live setting would not affect performance. We required participants to both physically and verbally indicate predicted serve direction. Specifically, participants held a racquet, and we asked them to stand as if they were facing a real serve, to perform a shadow return, and to say “left,” “body,” or “right.” The verbal response ensured that they clearly distinguished between the three possible serve directions. The verbal response was critical for “body” judgments because the participant could logically choose to make either a forehand or a backhand response. For all serves, we used the verbal response as the dependent variable. However, we observed no discrepancy between the verbal and physical responses for serves to the left and to the right.

**Free-recall test.** To obtain free reports of the information participants used to judge serve direction, we used a teachback protocol in which participants wrote responses to the question, “What advice would you give to someone wanting to judge the direction of serve for the player you have just seen?” To enhance further the sensitivity of the test, we showed participants the same unoccluded video clips that they viewed during the familiarization phase. Thus, the most pertinent cue that was available to participants for performing the anticipation test was also available during the free-recall test (Shanks & St. John, 1994). To assess relative rule
use in the three groups, we conducted a simple frequency count; we defined the unit of analysis with reference to information pertaining to the server, racquet, or ball.

Procedure

We informed participants that they would be shown video clips of tennis serves that we had filmed from the perspective of the player trying to return the ball. We showed them a diagram of a tennis court depicting the server position, the viewing perspective (i.e., the camera position), and the three possible directions for serves on the deuce and advantage sides of the court. We explained to participants that the server would direct the ball either to the left, to the right, or directly toward the camera and that they should respond in a timely fashion as if attempting to strike the ball. Participants were further informed that they should also verbally indicate their judgment and should then rate their confidence in the decision as 1, 2, 3, 4, or 5, where 1 corresponded to *not at all confident* and 5 corresponded to *extremely confident*. The experimenter then demonstrated the response requirements and informed each participant that there would be 6 s between each clip during which they should return to the starting position.

To familiarize participants with the experimental setup and response requirements, we presented them with video clips of 12 unoccluded serves that included ball-flight information. The serves were different examples from the same server who appeared in the test trials, and the serves comprised 2 serves to each direction (left, body, right) on each side of the court. On each trial, participants made a physical and a verbal response and expressed their confidence in their judgment, as per the requirements of the test phase. Before the test phase, we explained to participants that the ensuing video clips would not contain ball-flight information and that we had manipulated the images to remove various regions of the server. We then showed the 120 test trials in two blocks of 60 serves each separated by a rest period of approximately 2 min. At the end of the anticipation test, we gave participants another brief rest period and then completed the free-recall test. Last, we debriefed them about our purpose in the study. Overall, each participant took approximately 45 min to complete the experiment.

Results

We calculated the number of correct responses for each participant in each occlusion condition for serves to the
deuce side and the advantage side of the court. Preliminary analysis of the data revealed no significant difference between judgment accuracy for serves to the two sides of the court, $F(1, 34) = 1.51, p = .22$, and no higher order interactions with skill level. We therefore combined the data from the two sides of the court. We assessed the internal consistency of the anticipation test by using the split-half technique and applying the Spearman–Brown prophecy formula, entering the data for odd and even test items. That assessment revealed an acceptable reliability coefficient of .70. In addition, we examined possible test familiarity effects by comparing the mean number of correct judgments in the first and second halves of the test. A $5 \times 2$ (occlusion condition) analysis of variance (ANOVA) revealed nonsignificant effects of block number, $F(1, 36) = 0.11, p = .74$, and a nonsignificant interaction between block number and occlusion condition, $F(1, 144) = 0.36, p = .84$. Therefore, we proceeded with the main analysis. For all analyses, we set alpha at .05, and we indicate effect sizes with partial eta squared ($\eta^2$) values.

### Judgment Accuracy

The mean number of correct judgments by each group in each occlusion condition is shown in Figure 2. The skilled group attained mean accuracy scores of between 8.00 and 12.08 correct judgments out of 24, the recreational group attained mean accuracy scores of between 9.38 and 10.69 out of 24, and the novice group attained mean scores of between 8.27 and 10.00 out of 24. We conducted analysis of the judgment accuracy data by using arcsine transformations of the mean number of correct judgments in each occlusion condition. To determine whether the test discriminated between skill levels in the normal, unoccluded video, we first entered the transformed data from the no-occlusion condition into a one-way ANOVA. The analysis revealed a significant effect of group, $F(2, 34) = 3.51, p < .05, \eta^2 = .17$, and a Tukey honestly significant difference (HSD) post hoc test indicated that judgment accuracy was significantly higher for skilled players ($M = 12.08, SD = 2.25$) than for novices ($M = 9.45, SD = 1.75$). Mean judgment accuracy of the recreational players ($M = 10.69, SD = 2.90$) fell between those two levels and was not significantly different from that of either group.

To test the prediction that removing the tennis ball and the serving arm and racquet (arm + racquet) region would most impair performance of the skilled group, we conducted simple contrasts by using the arcsine-transformed data from the no-occlusion condition for comparison. As we predicted, the analysis revealed a significant interaction between occlusion condition and group in both the ball contrast occlusion condition, $F(2, 34) = 3.47, p < .05, \eta^2 = .17$, and the arm + racquet contrast occlusion condition, $F(2, 34) = 4.54, p < .05, \eta^2 = .21$. As can be seen in Figure 2, the skilled group suffered the largest drop in performance in both conditions, falling from a mean of 12.08 ($SD = 2.25$) to means of 8.00 ($SD = 2.55$) and 9.54 ($SD = 2.07$) in the ball occlusion condition and the arm + racquet occlusion condition, respectively. The interactions between occlusion condition and group were nonsignificant for the contrasts between performance in
the no-occlusion condition and performance in the lower-body and the whole-body occlusion conditions, $F$s < 1.0.

To test the prediction that the skilled group would still be able to perform above chance level when only the server’s head and the ball toss were visible, we conducted a binomial test for the skilled group’s data in the whole-body occlusion condition. Three of the 13 participants scored at chance level or below in that condition, whereas 10 scored above chance level. The proportion of the group that scored above chance (.77) was significantly higher than .50 ($p < .05$).

Overall, our analysis of performance in the unoccluded trials revealed skill-level differences in the expected direction. Removing information from the ball toss and from the arm + racquet region significantly impaired the skilled group’s direction judgments. However, significantly more than half of the skilled group were able to judge direction at above chance level when viewing only the server’s head and the ball toss.

**Confidence Ratings**

To compare the mean confidence ratings that were associated with judgments in the different conditions, we calculated mean confidence scores for each participant’s correct and incorrect responses in each of the five occlusion conditions. The resultant data satisfied the assumptions of normal distribution, equality of variance, and independence of observation. We therefore subjected them to ANOVA. We specifically entered the data in a $3 \times 2 \times 5$ (Group $\times$ Outcome $\times$ Occlusion Condition) ANOVA, which revealed a significant effect of outcome, $F(1, 34) = 67.50$, $p < .05$, $\eta^2_p = .67$, and occlusion condition, $F(2.54, 86.39) = 39.05$, $p < .05$, $\eta^2_p = .54$. The main effect of group ($p = .35$), all two-way interactions, and the three-way interaction were nonsignificant. Simple orthogonal contrasts revealed that confidence was significantly lower for judgments in conditions of ball occlusion ($M = 2.86, SE = 0.19$), arm + racquet occlusion ($M = 2.83, SE = 0.16$), and whole-body occlusion ($M = 2.47, SE = 0.14$) than for judgments in the conditions of no-occlusion ($M = 3.25, SE = 0.14$) and lower-body occlusion ($M = 3.27, SE = 0.14$). The interaction between outcome and occlusion condition approached significance ($p = .06$), which reflected the fact that the difference between confidence for correct and incorrect judgments tended to be smaller in the ball occlusion condition and, to a lesser extent, in the arm + racquet occlusion condition than in the other conditions (see Figure 3).

**Free Recall**

The information sources cited by participants as helpful for judging serve direction are summarized in Figure 4. They made 69 references specifying information for predicting serve direction. Two researchers independently classified those references, yielding an interrater reliability of 94.2% (65 out of 69 items). The two raters discussed the items that they originally classified differently until they reached consensus. The most frequently cited regions were the arm + racquet ($n = 19$), shoulders ($n = 11$), ball toss ($n = 10$), and stance and body orientation ($n = 9$). The mean number of information sources participants reported was greatest for the skilled group ($M = 2.31, SD = 0.48$), followed by the recreational group ($M = 1.85, SD = 0.55$) and the novice group ($M = 1.36, SD = 0.67$). A one-way ANOVA revealed
a significant main effect of group, $F(2, 36) = 8.21, p < .05, \eta_p^2 = .33$; and a Tukey post hoc HSD test indicated a significant difference between the mean number of information sources that the skilled and novice groups cited. Consistent with the judgment accuracy data, the skilled group most often reported that they used the arm + racquet position and the ball toss to judge serve direction. The recreational group most commonly referred to the arm + racquet region and also to the server’s shoulders; only 2 players cited the ball toss. As we indicated earlier, the novice group cited the fewest information sources; they most commonly made a global reference to the whole body.

**Discussion**

In the present study, we used the spatial or event occlusion paradigm to examine the advance information sources that skilled, recreational, and novice tennis players use in judging serve direction. In addition, we took both concurrent and retrospective measures of awareness in the form of confidence ratings on each trial, and we obtained postexperiment free reports of the information used during the test. Our rationale for using confidence ratings was that subjective awareness of the information supporting judgments should be reflected in higher confidence for correct than for incorrect judgments (Chan, 1992; Tunney & Shanks, 2003). Conversely, if participants are unaware of the information supporting their correct judgments, then researchers would expect that their confidence in correct and incorrect responses would not differ. In the anticipation test, participants observed video footage of serves that we temporally occluded on the final frame before racquet–ball contact and spatially occluded to selectively remove information pertaining to the ball toss, arm + racquet, lower body, and whole body.

The results were consistent with findings from studies of visual gaze behavior that have highlighted the importance of the ball toss, serving arm, and racquet for anticipation skill in tennis players (Goulet et al., 1989; Singer et al., 1998). In the present study, occluding either of those regions most significantly impaired the judgment accuracy of the skilled group in comparison with that in the unoccluded condition. One can see the importance of the ball toss in the present anticipation task most clearly by contrasting the skilled group’s performance in the ball occlusion and the whole-body occlusion conditions. Selectively removing the ball from the video left all postural information intact, yet the performance of the skilled group fell to chance level. That finding by itself could indicate either that the ball toss was important or that postural information was meaningful only when viewed in relation to the position of the ball. In the whole-body occlusion condition, however, we removed all postural information except the server’s head, yet significantly more than half of the participants in the skilled group performed above chance level. Vision of the trajectory of the ball toss in relation to just a single point of reference seemed to be sufficient to enable the skilled players to judge serve direction.

We add the following caveat to that interpretation: The ball toss was still visible when only the arm + racquet region was occluded. The contrast with performance in the unoccluded trials again revealed that the skilled group was most significantly impaired in that condition when participants were theoretically able to use information from the ball toss. In considering the nature of the different occlusion conditions, we speculate that the asymmetric image we formed by removing the arm + racquet may have drawn participants’ attention toward the server (and away from...
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with the judgment accuracy data in the no-occlusion condition, in the absence of feedback, it is perhaps unsurprising that the groups expressed similar levels of confidence. Had we given feedback, we might have expected participants' confidence relative to a common performance criterion. Consequently, we expected that their confidence would more closely reflect their performance. Remember, though, that we did not give participants feedback at any point during the experiment and that they never became aware of the accuracy of their judgments. Thus, the present task differs from a learning task in which one would expect performance improvements to be positively correlated with changes in confidence. In addition, Gigrenzer, Hoffer, and Kleinbötting (1991) noted in the context of general knowledge tests that the degree of confidence participants express depends on the reference class against which they judge the test items. Given the novel nature of the task, and in the absence of feedback, it is perhaps unsurprising that the groups expressed similar levels of confidence. Had we given feedback, we might have expected participants' confidence and performance to become better calibrated over time as they gained knowledge about the accuracy of their cue-based judgments (Runeson, Juslin, & Olsson, 2000).

Potential Limitations of the Present Study

An inherent limitation of studies in which participants make a judgment on the basis of the actions of a skilled performer is that researchers cannot be sure of the extent to which the results generalize to other performers. In the present study, we used an experienced coach who is a former professional player to generate the test stimuli. However, we do not know the extent to which the judgments that participants made and the information sources that they reported reflect the way they judge other servers and use those resources in actual play. If a greater number of performers were available, then researchers could use two or more of them to create the test stimuli. That change would allow researchers to perform within-test comparisons of performance and awareness across different actors (Jackson et al., 2006; Williams et al., 1999). It should additionally be noted that a sample of high skilled players may differ in the extent to which they attempt to disguise their intentions or deceive opponents. How much the present findings regarding both the performance data and the awareness data

the ball). In contrast, removing all postural information apart from the server's head forced participants to attend to ball toss information. Because of the unusual nature of images formed with the cloning technique, researchers could clearly benefit from combining the spatial occlusion paradigm with the analysis of point of gaze so that they can understand better how image manipulations affect visual search behavior.

Awareness

The results from the confidence ratings were largely consistent with the view that participants are aware of the sources of information driving their judgments. In particular, confidence was higher for correct than for incorrect judgments in the no-occlusion condition in all three groups. As can be seen in Figure 3, the difference between the confidence associated with correct judgments and the confidence associated with incorrect judgments was smallest when we occluded the ball, reflecting the fact that judgment accuracy was poorest in that condition. In contrast, there was a larger difference between confidence for correct judgments and confidence for incorrect judgments in the occlusion, lower-body occlusion, and whole-body occlusion conditions, in which judgment accuracy was generally at a higher level. The free-recall data corroborated those findings in the skilled group participants, who most frequently reported using information pertaining to the ball toss and the arm + racquet regions. In addition, the skilled players reported using significantly more information sources than novices did. Together, the findings form a pattern of results suggesting that skilled players' anticipation is accompanied by awareness of the information on which they base their judgments. Skilled tennis players most commonly reported using information from the ball toss and the arm + racquet regions to judge serve direction. When we selectively occluded that information, their judgment accuracy was impaired and their confidence in correct and incorrect judgments was less clearly distinguishable.

Evidence that awareness accompanied correct judgments was less clear in the recreational and novice groups. Their performance was generally at a lower level that that of the skilled group. Consistent with the notion that awareness accompanies correct judgments, both recreational and novice groups demonstrated higher confidence for correct than for incorrect judgments. However, the less skilled groups cited fewer information sources than the skilled group did, and the novice group most frequently referred generally to the whole body rather than to a specific region. Considered with the judgment accuracy data in the no-occlusion condition, the data suggested a progression from novices who perform at the lowest level, have low levels of awareness of one source of information, or view the image as a whole, to skilled players who focus on two or three specific regions, most particularly the serving arm and racquet and the ball toss. Furthermore, performance and free-recall responses became better aligned with each other with increasing skill, suggesting that increasing levels of awareness accompany improved perceptual discrimination in this task.

Regarding skill-level differences in confidence, we found no significant differences between groups across all five occlusion conditions. That finding is consistent with results of recent work showing no skill-level differences in judgment confidence in rugby union players (Jackson et al., 2006), yet it contrasts with the finding of Tenenbaum et al. (1996) that expert tennis players were less confident than their less skilled counterparts when judging ball-landing position from advance visual information. The highly skilled participants' higher expectations for how accurate they would be, as indicated by their response on the scaled diagram of the court, may have confounded the latter finding. In the present study, we used a discrete measure of performance (correct vs. incorrect) so that participants would express their confidence relative to a common performance criterion. Consequently, we expected that their confidence would more closely reflect their performance. Remember, though, that we did not give participants feedback at any point during the experiment and that they never became aware of the accuracy of their judgments. Thus, the present task differs from a learning task in which one would expect performance improvements to be positively correlated with changes in confidence. In addition, Gigrenzer, Hoffer, and Kleinbötting (1991) noted in the context of general knowledge tests that the degree of confidence participants express depends on the reference class against which they judge the test items. Given the novel nature of the task, and in the absence of feedback, it is perhaps unsurprising that the groups expressed similar levels of confidence. Had we given feedback, we might have expected participants' confidence and performance to become better calibrated over time as they gained knowledge about the accuracy of their cue-based judgments (Runeson, Juslin, & Olsson, 2000).
generalize to instances in which a player attempts to either disguise (i.e., delay the incidence or onset of discriminative information) or deceive (i.e., present misleading information) the observer remains an open question.

An additional limitation of the present study is that we did not fully address the question of whether performance impairment resulted from the removal of the selected local information (e.g., the serving arm) or from disruption of more global configural information specifying the relations between different regions (e.g., the movement of the arm in relation to the head). For example, both the ball toss and the arm + racquet region appeared important to the skilled group for judging serve direction. However, evidence about whether the individual information sources or the configuration of those sources underpinned judgments was mixed. On the one hand, removal of either source impaired performance, suggesting that the configuration of the two sources (perhaps in relation to a third source such as the server’s head) may be critical. On the other hand, the skilled group still performed well when viewing only the ball and the server’s head, suggesting that maintaining the configuration between the ball and the serving arm + racquet was not necessary for judging serve direction. Researchers examining other judgment tasks such as face recognition and the perception of biological motion have highlighted the importance of global processing of configural information (Bertenthal & Pinto, 1994; Diamond & Carey, 1986), and it seems likely that anticipation skill involves the processing of relations between different stimuli (e.g., Williams, Hodges, North, & Barton, 2006). However, the present results indicate that relatively low-level or local relations between two cues (the ball and the server’s head) or three cues (the ball, the server’s head, and the arm + racquet) may be sufficient.

In conclusion, we confirmed in the present study the importance of cues that researchers have identified through analysis of participants’ visual search and kinematic data as being likely sources of their information for making anticipatory judgments. The analysis of confidence ratings, together with the responses to the free-recall test, indicated that the skilled group’s awareness of the knowledge they used to make judgments accompanied their performance. In line with the use of subjective measures of awareness in implicit learning contexts (Chan, 1992; Tunney & Shanks, 2003), we suggest that by comparing participants’ confidence on correct and incorrect judgments, researchers can help to establish the nature of the judgments being made. Although researchers need to establish the extent to which the present findings generalize across other perceptual-judgment tasks, our method provides an additional, simple and unobtrusive means of assessing awareness that they can readily incorporate into existing testing protocols.

Biographical Notes

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REFERENCES

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