TEMPORAL CHANGE IN RESPONSE BIAS OBSERVED IN EXPERT ANTICIPATION OF VOLLEYBALL SPIKES

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Abstract

Anticipation is an important cognitive skill in sports. Although clear expert-novice differences in anticipation skills have been identified, it remains unclear whether the differences reflect purely perceptual processes, or include non-perceptual, judgmental component. To investigate this issue, we examined whether anticipation ability of expert volleyball players is affected by response bias in the context of signal detection theory. In the experiment, the participants observed video stimuli simulating offensive attack from the perspective of a defensive player and were required to judge attack type (spike or feint) and course (right or left). The video stimuli were cut off before or after the moment of hand-ball contact. Signal detection analysis showed that expert players were more sensitive than novices to differences between spike and feint and that experts were biased to judge an attack as a spike immediately before the spiker jumps. These results suggest that experts' prediction would be affected by response bias.

In high-level ball sports, successful performance requires accurate anticipation of forthcoming events under severe temporal constraints. In volleyball, the ball spiked by skilled female players lands on the opponent's court in only 0.6 sec from the impact of the spike (see Coleman, 1993), although, expert players are capable of receiving such balls. Previous studies in various sports have reported that experts are superior to novices not only in motor abilities but also in cognitive skills and players' anticipation ability depends on their level of experience (e.g., Abernethy, Gill, Parks, & Packer, 2001). In typical laboratory experiments, observers are presented with visual displays of playing actions, which are sometimes temporally and/or spatially occluded, and required to predict an outcome of the action. Experts' anticipation ability is examined with their response accuracy and/or reaction time (e.g., Williams & Burwitz, 1993). In studying the anticipation of expert volleyball players, the actions used in the experiments were a setter's toss (Wright, Gomez-Meza, & Pleasants, 1990) and a spiker's attack (Park, 2003). These studies have reported that the anticipation of experts is superior to that of novices. However, an important question is whether these experimental findings only reflect a player's visual ability to extract critical information contained in an opposing player's action. It may be that the player's judgmental processes, or response bias, contributed to these findings. In fact, Wright et al. (1990) suggested that expert players based their judgments of setter's toss direction on the likelihood of each possible direction at early occlusion points in which informative visual cues were not available. Applying signal detection theory (Macmillan & Creelman, 1991), Cañal-Bruland and Schmidt (2009) showed that handball goalkeepers were biased to judge a shooting action as a deception rather than a true attempt at shooting. These findings led us to hypothesize that experts' anticipation performance reflects not only perceptual processes, or sensitivity to visual information of play action, but also their response bias in judging the action. It may be that the role played by response bias changes as visual information available to the players becomes limited. To test this hypothesis, we compared expert volleyball players and novice counterparts in their anticipation performance to temporally occluded displays of spikers' attacking actions.

Method

Participants

The expert group consisted of 10 female volleyball players (mean age = 20.6 years, *SD* = 1.0). They were members of university volleyball clubs in Japan, with a mean playing experience of 8.8 (*SD* = 2.1) years. The novice group consisted of 10 female students (mean age = 21.2 years, *SD* = 1.2). They had limited experience of playing volleyball. All participants had normal or corrected-to-normal visual acuity and color vision, and they gave written informed consent prior to the experiment.

Stimulus production and design

We filmed attacking actions of three female volleyball players (mean age = 21.0 years, *SD* = 1.0) with a digital video camera (Panasonic HDC-HS300). They belonged to one of the teams in the Japanese top league and had a mean playing experience of 12.0 (SD = 1.0) years. We filmed a sequence of offensive play that began with a receiving action of serve by another player, followed by a setter's toss and the spiker's attack. The spikers were asked to demonstrate four different offensive plays, combinations of two types of attacks (spike and feint) and two directions (straight and cross-court), on the right side of their court viewed from the perspective of the opponent's court. 'Straight' was the direction parallel to the sideline of the volleyball court and 'cross-court' was the direction to the left-back corner from the spiker's position. The video camera was positioned at a height of 1.25 m and 11.72 m away from the center net in the defensive backcourt, simulating the eye level and view of a defensive player. The player's actions were filmed at a sampling rate of 30 frames per second. From the recordings of each player, 16 actions (4 actions each for four offensive plays) were chosen as the stimuli to be presented in the experiment. There were thus a total of 48 stimuli. The video stimuli were occluded at five time points relative to the moment of the spiker's hand contacting the ball:
t1: just prior to the spiker's running jump (-333 ~ -266 ms);
t2: 200 ms prior to the spiker's hand-ball contact (-200 ms);
t3: 100 ms prior to the spiker's hand-ball contact (-100 ms);
t4: the time of the spiker's hand-ball contact (0 ms); and
t5: 100 ms after the spiker's hand-ball contact (+100 ms).

In the experiment, the stimuli were projected on a screen using a projector (Panasonic TH-AE200) and subtended 22.7 × 40.0° of visual angle. A personal computer (DELL LATITUDE E6500) was used to control the experiment.

Procedures

Participants were seated about 2 m from the screen in a dark room. Before the experiment, the participants received an explanation about the types and courses of spikes to be presented. They were instructed to observe the video stimuli as if they were defenders trying to receive the ball, and to make four-alternative forced choice from 'left-spike', 'right-spike', 'left-feint', and 'right-feint', as accurately as possible. On each trial, a fixation point was presented at the center of the display for 1 sec, followed by the stimulus presentation up to a given occlusion point. Then the stimulus presentation was replaced with a response window, which showed four boxes corresponding to the four alternatives. The participants clicked one of the boxes using a computer mouse. Feedback was not provided after each response. Before the main trials, the participants were given practice trials until they became familiar with the stimuli and the task. Each participant completed two blocks of 120 trials that were randomized, with the 48 different stimuli occluded at five time points. Participants were given rest periods between blocks.

Results

Proportion of correct anticipation

Figure 1A shows the mean proportion of correct anticipation of both type and course as a function of temporal occlusion points for the experts and the novices. A 2 (Group) × 5 (Occlusion) analysis of variance (ANOVA) revealed that the main effect was significant for Group, $F(1, 18) = 24.34$, and Occlusion, $F(4, 72) = 372.21$, both $ps < 0.01$. The interaction between them was also significant, $F(4, 72) = 3.56$, $p < 0.05$. At every occlusion point except t5, the anticipation accuracy was higher for experts than for novices, all $ps < 0.01$.

The proportion of correct course anticipation, independent of judgments of attack types, was also individually calculated (Figure 1B) and submitted to a 2 (Group) × 5 (Occlusion) ANOVA. Both main effects were significant (Group, $F(1, 18) = 22.23$; Occlusion, $F(4, 72) = 321.94$, both $ps < 0.01$), as was the interaction between them, $F(4, 72) = 3.82$, $p < 0.01$. At t3 and t4, the course anticipation accuracy of experts was significantly higher than that of novices (both $ps < 0.01$).

Figure 1C shows the mean proportion of correct type anticipation, independent of judgments of attack courses, as a function of temporal occlusion points for the experts and the novices. A 2 (Group) × 5 (Occlusion) ANOVA showed that both main effects were significant (Group, $F(1, 18) = 24.34$; Occusion, $F(4, 72) = 372.21$, both $ps < 0.01$) and the interaction of Group × Occlusion, $F(4, 72) = 3.56$, $p < 0.05$, was also significant. The type anticipation accuracy was higher for experts than for novices at t1, $F(1, 90) = 15.78$, $p < 0.01$, and t2, $F(1, 90) = 4.91$, $p < 0.05$.

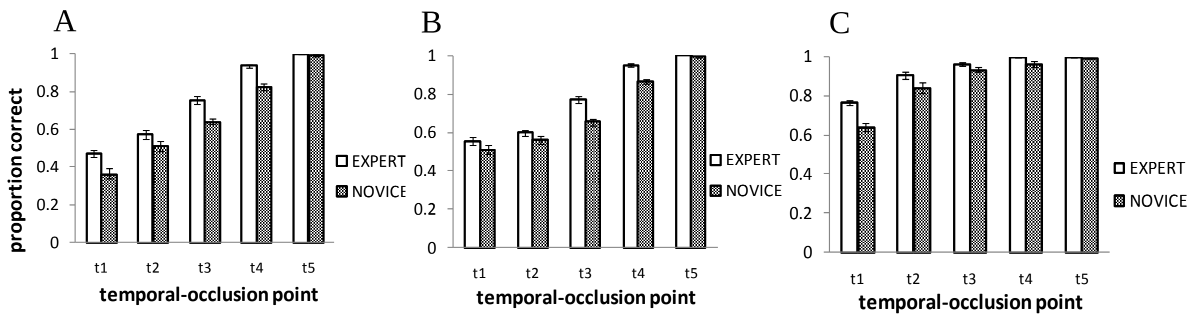

Figure 1. Mean proportion of correct anticipation of both type and course (A), course only (B), and type only (C) as a function of temporal occlusion points for the expert and novice groups. Error bars indicate standard error of the mean.

Sensitivity and response bias

The data for correct type anticipation, independent of course accuracy, were analyzed using signal detection theory (SDT) (see Macmillan & Creelman, 1991) as in Cañal-Bruland and Schmidt (2009). On spike trials, ‘spike’ and ‘feint’ responses were counted as hit and miss, respectively. Likewise, on feint trials, ‘spike’ and ‘feint’ responses were counted as false alarm and correct rejection, respectively. We calculated *d'* as a measure of sensitivity and *c* (criterion) as a measure of response bias (Cañal-Bruland & Schmidt, 2009, used β as a measure of response bias). Figures 2A and 2B show mean values of sensitivity (*d'*) and response criterion (*c*) for the attack type, respectively. A 2 (Group) × 5 (Occlusion) ANOVA was conducted separately for sensitivity and response criterion. For sensitivity (Figure 2A), the main effect of Group, $F(1, 18) = 13.10$, $p < 0.01$, the main effect of Occlusion, $F(4, 72) = 151.80$, $p < 0.01$, and the Group × Occlusion interaction, $F(4, 72) = 2.96$, $p < 0.05$, were all significant. Experts showed higher sensitivity scores than novices at t1, t2, and t4 (all $ps < 0.05$). For response criterion (Figure 2B), the main effect of Group was not significant, but the interaction of Group × Occlusion was significant, $F(4, 72) = 6.63$, $p < 0.01$. Experts were biased toward spike response at t1 ($t(9) = -3.479$, $p < 0.01$). Novices also exhibited bias toward spike response, but at different occlusion points, t2 ($t(9) = -2.658$, $p < 0.05$) and t3 ($t(9) = -2.470$, $p < 0.05$).

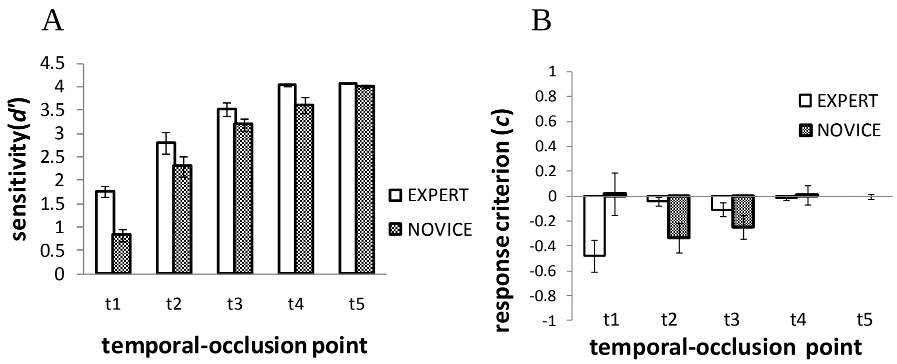

Figure 2. Mean values of sensitivity (A) and response criterion (B) for attack type as a function of temporal occlusion points for the expert and novice groups. For the right panel, positive and negative values indicate bias to 'feint' response and 'spike' response, respectively. Error bars indicate standard error of the mean.

The data for correct course anticipation, independent of type accuracy, were also analyzed by SDT. On left trials, 'left' and 'right' responses were counted as hit and miss, respectively. Likewise, on right trials, 'left' and 'right' responses were counted as false alarm and correct rejection, respectively. Figures 3A and 3B show mean values of sensitivity (*d'*) and response criterion (*c*) for the attack course, respectively. A 2 (Group) × 5 (Occlusion) ANOVA was conducted for sensitivity and response criterion. For sensitivity (Figure 3A), the main effect of Group, $F(1, 18) = 5.32$, $p < 0.05$, the main effect of Occlusion, $F(4, 72) = 181.30$, $p < 0.01$, and the Group × Occlusion interaction, $F(4, 72) = 4.00$, $p < 0.01$, were all significant. Experts were significantly better at anticipating than novices at t1 ($p < 0.01$) and t4 ($p < 0.05$). For response criterion (Figure 3B), a 2 (Group) × 5 (Occlusion) ANOVA was revealed that the main effect of Occlusion, $F(4, 72) = 71.00$, and the Group × Occlusion interaction, $F(4, 72) = 5.98$, were significant, both $ps < 0.01$. Experts were biased toward left response at t1 ($t(9) = -6.43$), t2 ($t(9) = -15.01$), t3 ($t(9) = -8.77$), and t4 ($t(9) = -2.470$), all $ps < 0.05$. Novices also showed bias toward left response at t1($t(9) = -2.49$), t2 ($t(9) = -13.04$), t3 ($t(9) = -11.59$), and t4 ($t(9) = -2.71$), all $ps < 0.05$.

In order to compare the sensitivity for type (Figure 2A) and for course (Figure 3A), a 2 (Response Categaroy; type and course) × 5 (Occlusion) ANOVA was conducted separately for experts and novices. For both groups, the main effect of Response Category ($F(1, 9) = 146.38$ for the expert and $F(1, 9) = 13.13$ for the novice groups, both $ps < 0.01$) and the main effect of Occlusion ($F(4, 36) = 84.11$ for the expert and $F(4, 36) = 131.80$ for the novice groups, both *ps* < 0.01) were significant. The Response Category × Occlusion interaction was also significant for both groups ($F(4, 36) = 51.10$ for the expert and $F(4, 36) = 9.67$ for the novice groups, both *ps* < 0.01), indicating that the sensitivity for the attack course reached a plateau at later occlusion points than that for the attack type. The sensitivity was significantly higher for type than for course at t1-t3 for both groups (all *ps* < 0.01).

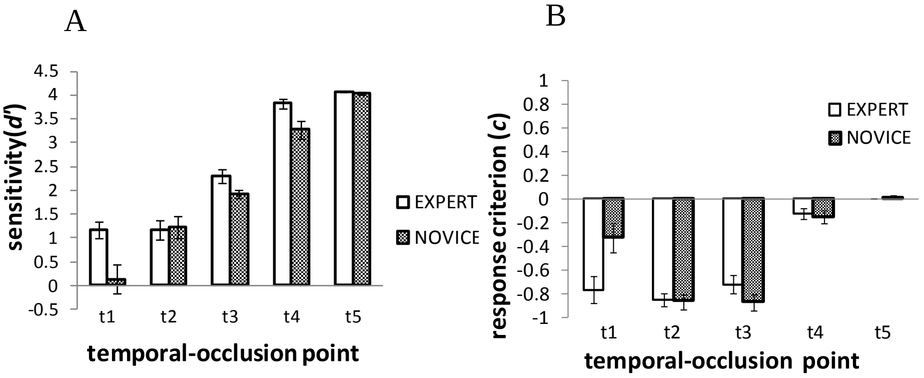

Figure 3. Mean values of sensitivity (A) and response criterion (B) for attack course as a function of temporal occlusion points for the expert and novice groups. For the right panel, positive and negative values indicate bias to ‘right’ response and ‘left’ response, respectively. Error bars indicate standard error of the mean.

Discussion

In this study, we found that the anticipation accuracy increased as the occlusion point advanced for both groups (experts and novices), and the experts performed better than novices, which is consistent with previous studies (e.g., Williams & Burwitz, 1993; Wright et al., 1990).

This research revealed that response bias as well as sensitivity to a spiker’s actions contributes to anticipation in volleyball defense. In anticipating attack type, both groups were biased to give a response of ‘spike’ but experts exhibited the bias at earlier occlusion points than novices. This indicates that playing experience had an effect on decision making during play. Salmera and Fiorito (1979) suggested the existence of decision-making strategies when faced with severe time constraints (see Williams, 1999). When we apply the strategies to volleyball players’ anticipation strategies in this study, the response bias favoring ‘spike’ may be caused by the following two factors: (i) the players estimated the probability of spikes to be higher than that of feints, (ii) players’ actions for hitting spikes were more correctly identifiable than those for performing feints. The former factor is relevant to the players’ response bias favoring spikes. The players’ overestimation of spikes, if it exists, would reflect situational probabilities, whether subjective or real, of attack types in many games that they had played (see Abernethy et al., 2001; Alain & Proteau, 1978, Cañal-Bruland & Schmidt, 2009). The present study suggests that experts are more likely to rely on subjective probabilities in predicting attack type when informative cues in a visual display are less available (Mori, 1988). The latter factor, relatively high identifiability of spike actions, might be related to biased decision criteria toward ‘spike’ responses by the experts and the novices. In the context of signal detection theory, such high identifiability of spike stimuli can be represented by non-equal variance of two internal distributions corresponding to spike and feint actions: the distribution for spike actions has smaller variance than that for feint actions. Further studies are needed to test this possibility.

The result that the sensitivity for the course judgments reached a plateau at later occlusion points than that for the type judgments indicates that cue information necessary for correct course anticipation becomes available later than that for type anticipation. This is consistent with the post-experiment interviews with the players who reported that the orientation and spatial position of the spiker relative to the ball to be hit, which are available just prior to hand-ball contact, are important cues in anticipating attack course.

In anticipating attack course, both groups were biased towards favoring a ‘left’ response. This might be due to the position of spikers in the filmed stimuli used in the present study. Perhaps observers thought that spikers on the right side of the offensive court (viewed from the defensive court) would attack more often to the left than to the right side of the defensive court because the left side was wider on the court than the right side from their position.

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