Tech., Inst., Cognition and Learning, Vol. 9, pp. 295–312
Reprints available directly from the publisher
Photocopying permitted by license only

An Expertise Approach to Training Anticipation Using Temporal Occlusion in a Natural Skill Setting

SEAN MÜLLER*,[1] AND BRUCE ABERNETHY[2]

[1]*School of Psychology and Exercise Science, Murdoch University, Perth Australia*
[2]*School of Human Movement Studies, University of Queensland, Brisbane Australia*

Anticipation skill was trained through temporal occlusion using vision occlusion spectacles. A with-movement training group had vision occluded as they batted against bowlers, while the without-movement training group's vision was occluded as they stood behind a net and made a verbal prediction of ball types. Intervention groups and a control group also participated in sports-specific practice. Training benefits, assessed using video simulation and in-situ anticipation tests, were found for the anticipation of short length but not full length deliveries. The with-movement group performed better on the video simulation test than the control group after training. In the in-situ test, both training groups showed improvements from pre- to post-test of foot movements made when vision of ball flight was deprived. This enhanced body positioning translated into an improvement in quality of bat-ball contacts for only the with-movement group. Temporal occlusion training appears to have some selective benefits to improve anticipation expertise.

Keywords: Expertise, anticipation, perceptual training, temporal occlusion, perception-action coupling, cricket batting

In sports such as cricket, baseball and tennis, complex, environmentally-appropriate movements must be completed with precision in less than a second. Expert players cope with these severe time constraints by picking-up early visual information from the opponent's movement patterns in advance of ball flight and then use this information to anticipate stroke or ball type (Müller & Abernethy, 2012), as well as guide the early organization of an appropriate

*Corresponding author: s.muller@murdoch.edu.au

interceptive movement response. Because of the importance of anticipation to expert performance, finding optimal methods of training anticipation is essential for players, coaches and scientists alike.

A number of previous studies have investigated the efficacy of video simulation training as a means of enhancing anticipatory skill in different sports. In the video simulation approach, the sports-specific scene is filmed from a player perspective and then systematically replayed and repeated with the footage temporally occluded at different points in time. After occlusion, the viewer is typically required to make either a verbal or written response as to the predicted action of the opponent and then, after this judgement is made, the unoccluded footage is then shown as feedback. Studies taking this approach have reported improvements in judgement of stroke direction and number of serves returned in tennis (Haskins, 1965), serve prediction accuracy in tennis (Farrow & Abernethy, 2002), as well as prediction of pitch type and location in baseball (Burroughs, 1984; Fadde, 2006) that have transferred from video temporal occlusion training to a perception-action coupled motor skill test. Other studies that have used video-based temporal occlusion training and video-based testing have reported pre- to post-training improvements in prediction accuracy of tennis groundstroke type and direction (Day, 1980; Singer et al., 1994), ball location and goals blocked in soccer goalkeeping (McMorris & Hauxwell, 1995), decision time and prediction of offensive play in basketball (Starkes & Lindley, 1994), decision time for return of tennis serve (Farrow, Chivers, Hardingham & Sachse, 1998) and prediction of stroke depth/direction in badminton (Abernethy, Wood & Parks, 1999)

A smaller number of studies have also investigated anticipatory training in natural skill settings where rather than simply making a verbal or written response the participants are required to execute an interceptive movement (e.g., to strike a ball). An early study by Osborne, Rudrud and Zezoney (1990), for example, used colour to highlight the seam of curveballs delivered from a projection machine and reported improvements in hitting accuracy of 2–7%. Later studies that have provided visual attention training (Adolphe, Vickers & Laplante, 1997 with volleyball serve reception and pass accuracy) or required a set point of gaze (Harle & Vickers, 2001 with basketball free throw) have reported improvements that make both the visual search patterns of the participants more expert-like and provide some pre- to post-test training improvement in the performance of field-based tests.

Occlusion-based testing and training situations that do not require a movement response may invoke the use of functionally different neural pathways for the processing of visual information than those that do. It has been suggested that the dorsal visual stream is responsible for visual control during movement (*vision-*

for-action) and that the ventral visual stream is responsible for gleaning visual meaning of the environment when there is no movement (*vision-for-perception*) (Milner & Goodale, 1995). Striking sport skills that require a movement response may rely to a greater extent upon the dorsal vision-for-action stream than the ventral vision-for-perception stream. Accordingly, theoretical concepts of ecological validity, representative task design and perception-action coupling appears critical during testing to engage the underlying processes of visuomotor control that exist in natural performance contexts (see Farrow & Abernethy, 2003). To this, research using an expertise paradigm with in-situ temporal occlusion has varied response mode in a natural skill setting and found greater anticipatory performance differences between experts and novices with a movement response than without a movement (Farrow & Abernethy, 2003). Therefore, anticipatory training with-movement might be expected to provide greater performance benefits, than without-movement training, because with-movement training is more closely related to the underlying processes activated during striking skills. Little, however, is known of the value of responses with or without a movement to anticipatory training in a natural skill setting.

In this study we used what is known from an expertise paradigm in the exemplar motor skill of cricket batting to improve anticipatory skill in a group of cricket batsmen. This motor skill provided a useful model because bowlers use various strategies in an attempt to cause less than optimal skill execution in batsmen. Firstly, a swing bowler may use high ball velocity (above 110 km/h) to place time stress upon responding for a batsman. Accordingly, the travel time of the ball from the bowler's release position to the required instance of bat-ball contact may be less than the total response time of the batsman to prepare and execute a stroke (Abernethy, 1981), necessitating anticipatory responding to prepare at least a component of the stroke (foot movements) based upon pre-ball flight information. Secondly, a swing bowler imparts swing on the ball that causes the ball to deviate laterally in flight or after bouncing making prediction of the landing position of the ball and its spatial position for bat-ball interception difficult. Thirdly, a swing bowler can vary the landing position of the ball with the purpose of altering the bounce height for bat-ball interception. Balls that land closer to the batsman (full length) bounce lower, necessitating a forward foot movement to position the body optimally for interception, while balls that land further away from the batsman (short length) bounce higher, necessitating a backward foot movement to best position the player for interception. A single skill error by the batsman due to the foregoing strategies used by the bowler can result in the batsman being dismissed ('given out') and ending their participation in a match. To be able to cope with the foregoing constraints, expertise studies that have examined anticipation in cricket batting using video simulation temporal and spatial occlusion have reported the capability of expert batsmen (of international standard), but not less skilled players, to be able to utilise advance pre-ball flight information to predict delivery type (see Müller, Abernethy & Farrow, 2006). In-situ temporal occlusion using liquid crystal glasses worn by the participant has shown that expert cricket batsmen (state or provincial level) use advance information to guide body positioning in terms of foot movements (see Müller et al., 2009), whilst ball flight information is used for positioning and fine tuning the striking implement for interception (see Müller & Abernethy, 2006; Müller et al., 2009). Therefore, if anticipatory training can enhance the expertise of a batsman in the capability to pick-up visual information to better achieve gross body positioning and bat-ball interception, it may allow the batsman to effectively combat the strategies used by their opponents (the bowlers) to induce skill errors.

The specific purposes of this investigation were: (i) to use what is known from expertise research into the exemplar motor skill of cricket batting to improve anticipatory skill in less skilled batsmen, (ii) determine if occlusion-based training could induce improvements in anticipation above and beyond that due to normal (conventional) cricket batting training and (iii) to compare the efficacy of occlusion training done with and without the use of a coupled interceptive movement response. The pre- to post-training changes in performance on a video simulation test of anticipation and an in-situ test of batting were compared between three groups – a group given occlusion training without a movement response, a group given occlusion training with a coupled interceptive response and a control group given only the normal cricket training practice that was also experienced by the two occlusion training groups. Based upon the empirical evidence as well as theoretical constructs of ecological validity, representative task design and perception-action discussed earlier it was hypothesised that: (i) temporal occlusion training undertaken either with or without movement would provide superior anticipation benefits compared to the sports-specific practice (control) group and (ii) temporal occlusion training with-movement would provide a greater anticipatory training benefit than temporal occlusion training without-movement.

METHOD

Participants

Male cricket batsmen that competed in either the first, second or third grade competitions in Australia were recruited from four different district cricket clubs and assigned in a quasi-random manner to the with-movement ($n = 9$), without-movement ($n = 8$) and control ($n = 6$) groups. Grade competition refers to the club competition below first class (or state/provincial) level cricket. First, second and third grade refers to respective divisions within the club competition. Mean ages of the participants in each group were 19.89 ($SD = 3.79$), 23.38 ($SD = 10.65$) and 21.30 ($SD = 4.62$) years, respectively. Players from higher and lower competitions were distributed across the experimental and control groups as equally as possible. Three swing bowlers from each club were also recruited to bowl to the batsmen. Due to logistical difficulties in testing, different groups of bowlers were used for each of the experimental groups, with each group of bowlers delivering balls to their respective group of batsmen across testing phases. The velocity that the bowlers delivered the balls, however, was kept consistent across each of the experimental groups (see below). The batsmen were familiar with the bowlers as they participated together in intra-club practice. The intervention was implemented within a club, with bowlers known to the batsmen, in order to create a realistic learning environment - the purpose of within-club or squad practice is generally to improve skill performance. This experiment was approved by the institutional Human Research Ethics committee. All participants provided informed consent prior to participating in the experiment.

Experimental Design and Testing Procedures

A pre-and post-test control group design was used. Each participant (batsman) was tested before and after the training intervention using two previously validated cricket batting anticipation tests, viz., the video simulation test developed by Müller et al. (2006) and the in-situ batting test developed by Müller et al. (2009). The design of these tests was not altered to preserve their construct validity. The purpose of the video simulation test was to examine the capability to use advance information, whilst the purpose of the in-situ batting test was to examine the capability to use advance and/or ball flight information when attempting to strike a delivered ball.

In both the video and in-situ batting tests three ball types were used: (i) a full length outswinger, (ii) a full length inswinger and (iii) a short length ball. A full length outswinger is a ball that swings in the air from left to right from the viewing perspective of a right-handed batsman and lands quite close to the normal stance position of the batsman. A full length inswinger refers to a ball that swings in the air from right to left from the viewing perspective of a right-handed batsman and also lands close to the stance position of the batsman. A short length ball lands further away from the batsman and bounces much higher by the time it arrives at the batsman. The appropriate movement response to the full length deliveries is to play the ball by stepping forward with the weight on the front foot, whereas for the short length delivery the appropriate response is to play back with weight transferred to the rear (back) foot. Balls were delivered by the bowlers at velocities estimated to range between 90–100 km/h. Velocity was calculated from the high-speed video footage based upon the formula: velocity (m/s) = distance of 17.72 m from batsman to bowler divided by time (ms) determined by transit time of the ball from ball release by the bowler till bat-ball contact, and then, converted to km/h. The actions of the batsmen and bowlers were filmed using high-speed cameras (sampling at 200 frames per second) in order to both quantify and cross-check the timing of vision occlusion and quantify the appropriateness of the foot movements made by the batter. Quality of bat-ball contact was assessed 'live' by a trained research assistant (blind to the experimental groups) who made a categorical qualitative rating and then recorded the rating in a data sheet (see Müller & Abernethy, 2008 for validity and reliability of this rating).

The video simulation test included vision of a swing bowler bowling a number of different types of deliveries with the display temporally occluded at one of four different points on each trial, viz., the moment of back-foot impact (BFI), front foot impact (FFI), ball release (R) or after the ball had been released and passed the batsman without occlusion (NO). Participants were required to watch the footage until temporal occlusion and tick in an answer booklet their judgement as to which one of three different ball types was being delivered (see below for further detail).

The in-situ batting test involved the batsman wearing vision occlusion spectacles (Milgram, 1987) that allowed the experimenter control over the timing of when the batsman's vision was occluded as the batsman attempted to bat normally against a swing bowler. The spectacles proceeded from an open position (that permitted vision) to a closed position (that occluded vision). Closing of the spectacles was manually triggered through a remote hand held button press controller (see Müller et al., 2009 for further details). Due to difficulty associated in manually triggering the occlusion glasses at pre-planned events in the bowler's action and ball flight, trials needed to be post-hoc sorted from the available high-speed video footage prior to analysis in order to ensure that they were correct in relation to the pre-planned vision occlusion conditions. Three vision conditions were presented wherein the batsman's vision of the delivered ball was either: (i) occluded as close as possible to the point of ball release (*pre-release occlusion*, where only advance or pre-ball flight information could be viewed), (ii) occluded as close as possible to the point of ball bounce (*pre-bounce occlusion*, where advance and early ball flight could be viewed), or (iii) not occluded (allowing all advance, ball flight and ball bounce information to be viewed).

The video simulation test included 48 trials consisting of three ball types x four temporal occlusion conditions x four repeats. The in-situ test included batsmen facing 45 trials (balls) consisting of three ball types x three temporal occlusion conditions x five repeats. Trials were post-hoc sorted from the high-speed video record to ensure they were the correct occlusion condition/delivery type and then subjected to statistical analyses. Table 1 provides details of the timing of temporal occlusion and trial numbers experienced (after post-hoc sorting) in the in-situ test by the experimental/control groups.

Training Procedures

During the training phase, the two temporal occlusion training groups each received a total of six training sessions each consisting of 36 deliveries bowled by swing bowlers who were different to those used in the in-situ batting test. The training phase lasted six weeks with one session per week. The 36 trials of occlusion training experienced in each session consisted of three ball types (as used in testing) x three temporal occlusion conditions (as used in testing) x four replications. In the first three weeks, three consecutive blocks of 12 trials were presented including easy to hard temporal occlusions (i.e., no occlusion, pre-bounce and pre-release, respectively). In the remaining three weeks, temporal occlusion was randomised to increase training stimulus difficulty.

Training was conducted on either an outdoor synthetic turf or a grass turf cricket pitch and the batsmen were required to attempt to strike bowled softer cricket balls (same ball used during the in-situ test) while their vision was temporally occluded through triggering of the occlusion spectacles they wore. The with-movement group were instructed to bat as they would in a match situation with the goal of scoring runs and not being dismissed. The without-movement group stood behind a net where a batsman and bowler were practising and made a verbal prediction of deliveries (e.g., full length outswinger) while their vision was temporally occluded. Feedback was provided relative to the response modes of the training groups for occluded trials by the experimenter. For the with-movement group, verbal feedback provided an indication of the delivery type (e.g., full length outswinger) and the direction the ball was struck, whilst for the without-movement group verbal feedback was provided of the delivery type only as this group had no motor response. No instructions were given to either groups regarding when or what to attend to during the training. Both temporal occlusion training groups also participated in weekly club cricket practice during the training/test phases and matches on the weekends. In contrast, the control group participated only in their club cricket practice during the week and matches on the weekends.

TABLE 1
In-situ batting test time of temporal occlusion (M & SD in parentheses) and trial numbers after post-hoc sorting relative to groups, occlusion conditions, ball length and testing phases.

Measure	Group	Experimental Condition											
		Pre-Release Occlusion				Pre-Bounce Occlusion				No Occlusion			
		Full Length		Short Length		Full Length		Short Length		Full Length		Short Length	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Occlusion	1	38.21 (19.81)	50.79 (18.21)	37.82 (9.48)	40.97 (11.92)	246.82 (52.12)	269.24 (54.57)	160.63 (53.43)	153.38 (31.83)	–	–	–	–
Time	2	45.90 (17.84)	32.31 (11.78)	30.05 (13.28)	27.94 (5.47)	287.93 (29.03)	272.84 (57.12)	156.02 (58.86)	182.53 (28.07)	–	–	–	–
(ms)	3	41.66 (15.31)	37.05 (16.11)	29.65 (17.73)	42.22 (20.94)	262.29 (16.03)	271.83 (48.13)	175.82 (22.53)	158.26 (39.73)	–	–	–	–
Trial	1	45	47	27	18	59	70	26	38	48	73	30	39
Numbers	2	38	30	23	22	63	58	28	38	39	44	26	32
(n)	3	25	16	16	13	36	36	21	20	32	30	32	29

Note. Occlusion time represents the time that vision was occluded prior to ball release and prior to ball bounce in milliseconds. Group numbers 1, 2 and 3 refer to with-movement, without movement and control groups, respectively.

Consistency of Vision Occlusion Conditions, Dependent Measures and Analysis of Data

Prior to analysis of the dependent measures, between-group comparisons were made to check that vision was occluded at consistent time points prior to the event of ball release and prior to the event of ball bounce for the in-situ test. One-way analysis of variance revealed no significant differences between-groups in timing of vision occlusion in the pre-test or post-test occlusion conditions (ps $>$. 05). Due to the difficulty of creating occlusion conditions mentioned earlier, this limited the distribution of trials between-groups. Therefore, sufficient control over the timing of vision occlusion prior to the events was consistent between-groups across testing phases in the batting test.

The dependent measure for the video simulation test was overall prediction accuracy for ball types with chance/guessing level of 33.33%. The prediction of ball type is a typical measure for vision-for-perception types of judgements. For the in-situ batting test that purportedly requires more vision-for-action types of processing, two dependent measures were derived from the actual movement responses of the participants: (i) the percentage of appropriate definitive foot movements (length judgement) with chance/guessing level of 50% and (ii) the percentage of 'good' bat-ball contacts that were attained (using the methods described in Müller et al., 2009). A definitive foot movement was defined as the final foot movement made forward or backward in order to strike a delivered ball. 'Good' bat-ball contact was defined as a ball that was struck (with the blade of the bat) and was translated in the direction that the bat was swung. To prevent experimenter bias, all data were coded by a trained research assistant blind to the experimental groups and specific purposes of the experiment.

Previous research has reported that prediction of ball length is a critical factor to skilled performance in cricket batting (see Land & McLeod, 2000; Müller et al., 2009), which justifies separation of ball length for further analyses. For both the video simulation test and the in-situ batting test, the responses given to the trials involving balls of full length were first separated from those involving short length deliveries and then a series of factorial ANOVAs were run on each dependent measure for each of the different delivery lengths (this is consistent with previous work, see Müller et al., 2009). The factors in the analysis were group (3 levels), test phases (2 levels; pre and post-training) and occlusion (4 levels for the video test and 3 levels for the in-situ test) with the last two factors being repeated measures. The sources of any main effects and interactions were examined using syntax simple main effects and post-hoc pairwise comparisons in SPSS. Alpha was set at .05 and a Greenhouse-Geisser correction was applied in any instances where the assumption of sphericity was violated. No correction was made to the alpha level as this experiment was a first of its kind and corrections such as Bonferroni can be conservative (see Perneger, 1998). Partial eta-squared η_p^2 effects sizes derived from the F-test were used to examine the magnitude of mean differences. Percentage accuracy scores for the prediction of ball type in the video test were also tested against the guessing level of 33.33% using one-sample t-tests and a comparable analysis was also conducted for the foot movement responses in the in-situ test (guessing level of 50%).

RESULTS

Video Simulation Test

Figure 1 separately shows prediction accuracy for ball type for groups relative to testing phases and occlusion conditions for (i) the full length deliveries and (ii) the short length deliveries in the video simulation test. For the full length deliveries, no significant effects were found for training group either overall or in interaction with test phase or occlusion (ps $> .05$). The only significant effect that was observed was a main effect for occlusion $F(3, 60) = 74.96$, $p < .05$, $\eta_p^2 = .78$ due to higher accuracy scores on the no occlusion condition compared to all other conditions. In contrast, for the short length deliveries, while there was again a main effect for occlusion due to the superior performance on the no occlusion conditions $F(3, 60) = 12.89$, $p < .05$, $\eta_p^2 = .39$, there was also a significant main effect for group $F(2, 20) = 3.65$, $p < .05$, $\eta_p^2 = .26$ and a significant interaction between group and testing phases $F(2, 20) = 3.58$, $p < .05$, $\eta_p^2 = .26$. The group x test interaction was due to a significantly greater accuracy score for the with-movement training group ($M = 39.85$, $SD = 9.16$) compared to the control group ($M = 18.75$, $SD = 11.22$) at post-test, but there was no significant difference between with-movement and without-movement groups or without-movement and control in the post-test (ps $> .05$). At pre-test the accuracy scores of the three groups were not significantly different. The with-movement training group also showed the only instance of a pre- to post-test change in prediction accuracy from guessing level to superior than guessing level – this occurring for the release point (R) occlusion condition (pre-test: $t(8) = -.63$, $p > .05$; post-test: $t(8) = 2.77$, $p < .05$).

In-Situ Batting Test - Foot Movement Accuracy

Figure 2(a) and (b) plot the accuracy in producing the appropriate definitive foot movement for balls that are either full or short in length, respectively, for the in-situ batting test. Accuracy is shown as a function of the time of testing (pre- v

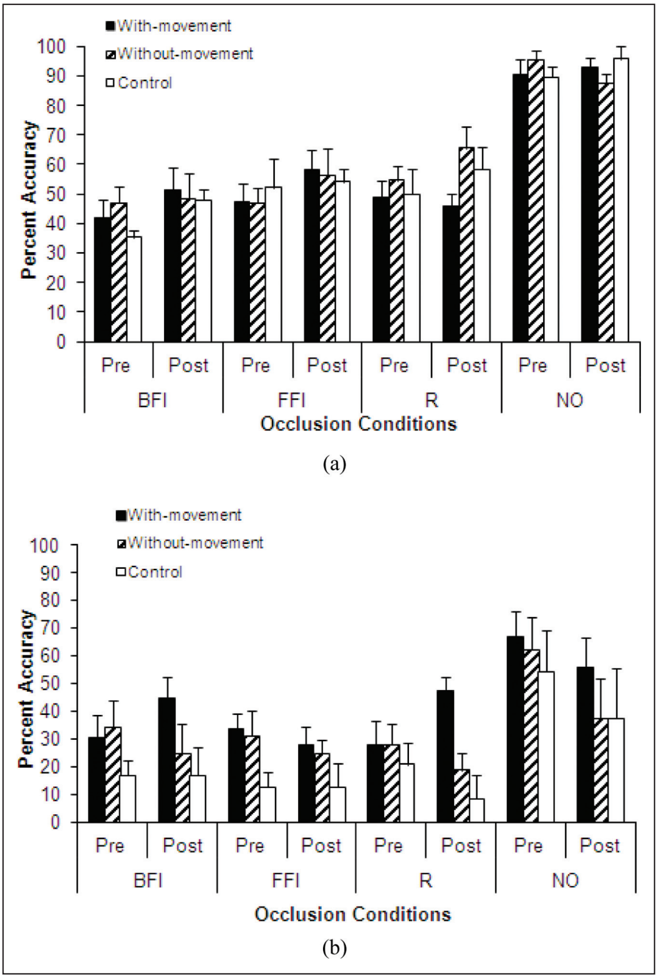

FIGURE 1
Prediction accuracy of ball types for full length deliveries (**a**) and short length deliveries (**b**) for groups relative to testing phases and temporal occlusion conditions in the video test. Temporal occlusion conditions include; back-foot impact (BFI), front-foot impact (FFI), ball release (R) and no occlusion (NO). Pre and post refer to pre-test and post-test, respectively. Error bars show standard errors of the mean.

post-training) and the time at which the display was temporally occluded. For the full length deliveries there were no significant main effects attributable to the factors of group membership, time of testing or occlusion, plus no significant interactions between these factors. There was also no change for the groups in accuracy of foot movements in relation to the guessing level across pre- to post-tests. In

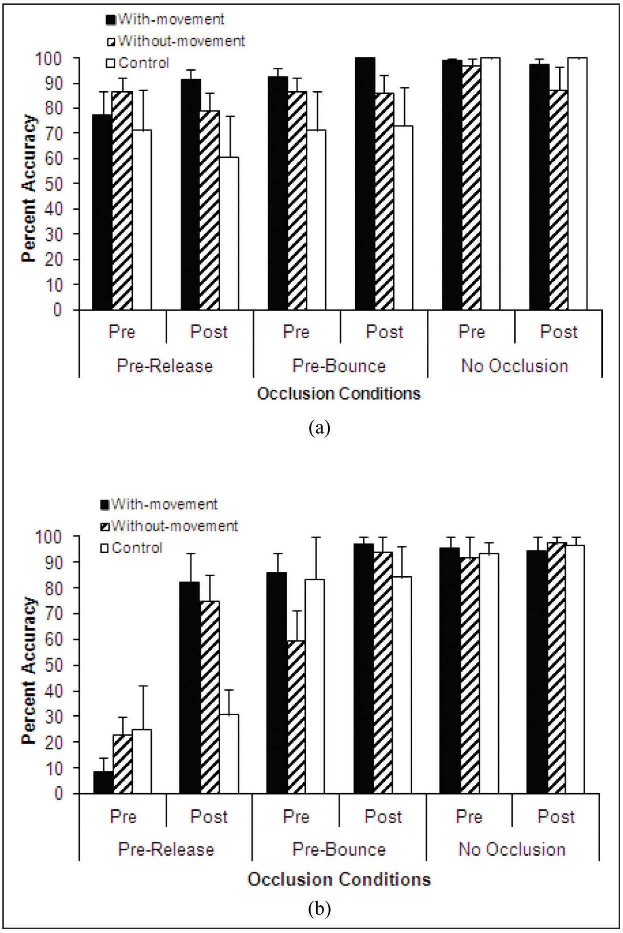

FIGURE 2
Percentage accuracy of definitive foot movements (length judgement) for balls bowled at a full length (**a**) and short length (**b**) for groups relative to testing phases and temporal occlusion conditions in the batting test. Pre-release refers to temporal occlusion prior to ball release; pre-bounce refers to temporal occlusion prior to ball bounce; no occlusion refers to all vision was available. Pre and post refer to pre-test and post-test, respectively. Error bars show standard errors of the mean.

contrast, for the short length deliveries, a significant three-way interaction was obtained $F(4, 40) = 3.42$, $p < .05$, $\eta_p^2 = .25$. Follow-up analyses indicated that the source of the interaction was a significantly greater accuracy in length judgement by the two occlusion training groups ($M = 82.40$, $SD = 19.72$; $M = 75.00$, $SD = 20.96$, for with and without-movement groups, respectively) over the control group ($M = 30.55$, $SD = 24.16$) at the pre-release temporal occlusion in the post-test ($p < .05$). No significant difference was evident between the three groups at the same occlusion point in the pre-test, indicating that the two occlusion training groups but not the control group had improved their foot movement length responses pre-release as a consequence of the occlusion training they had experienced. Accuracy of foot movements for the two training groups at the pre-release temporal occlusion condition improved from significantly below chance level (pre-test: $t(8) = -7.07$, $p < .01$, with-movement, $t(7) = -3.87$, $p < .01$, without-movement) to above chance (post-test: $t(8) = 2.90$, $p < .05$, with-movement, $t(7) = 2.51$, $p < .05$, without-movement) across pre- to post-tests, whilst the control group remained at chance level at the same occlusion condition over testing phases.

In-Situ Batting Test - Bat-Ball Contact Accuracy

Figure 3(a) and (b) shows the percentage occurrence of 'good' bat-ball contacts for groups relative to testing phases and temporal occlusion conditions for the full and short length deliveries, respectively, in the in-situ batting test. The analysis of the full length deliveries failed to reveal any significant main or interactive effects ($p > .05$). For the short length deliveries, there was a significant interaction between groups and testing phases $F(2, 20) = 4.57$, $p < .05$, $\eta_p^2 = .31$ but no other significant effects and no differences between groups in the pre-test. The interaction was due to the significantly superior overall improvement in 'good' bat-ball contacts by the with-movement group (Pre-test, $M = 24.01$, $SD = 8.34$; Post-test, $M = 37.13$, $SD = 7.52$) over the without-movement (Pre-test, $M = 31.57$, $SD = 8.80$, Post-test, $M = 33.39$, $SD = 9.20$) and control (Pre-test, $M = 31.01$, $SD = 10.22$; Post-test, $M = 20.03$, $SD = 9.36$) groups across the temporal occlusion conditions and testing phases ($p < .05$).

DISCUSSION

When a sports performer is faced with time stress, such as when a cricket batsman competes against a swing bowler, pick-up of early visual information for anticipation of ball type is critical to allow early body positioning for efficient bat-ball interception. The purpose of this investigation was, firstly, to use previous evidence on expertise in the exemplar motor skill of cricket batting to improve anticipatory skill. Secondly, to compare performance on tests of anticipation between groups given temporal occlusion training as well as sports-specific practice to a control group that received only sports-specific cricket

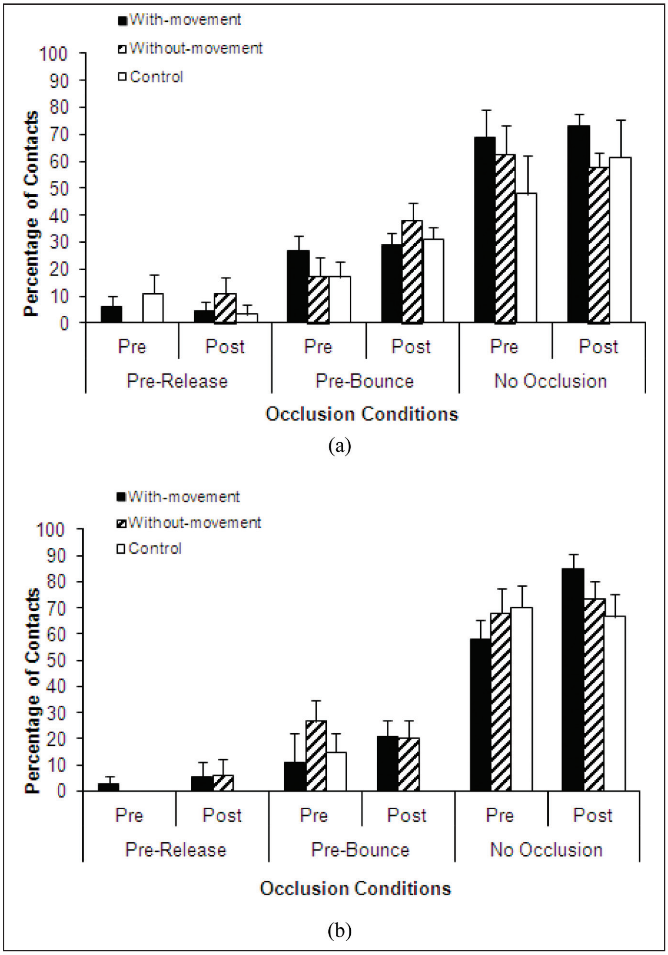

FIGURE 3
Percentage of 'good' bat-ball contacts for balls bowled at a full length (**a**) and short length (**b**) for groups relative to testing phases and temporal occlusion conditions in the batting test. Pre-release refers to temporal occlusion prior to ball release; pre-bounce refers to temporal occlusion prior to ball bounce; no occlusion refers to all vision was available. Pre and post refer to pre-test and post-test, respectively. Error bars show standard errors of the mean.

practice. Thirdly, the purpose was to examine the comparative value of temporal occlusion anticipatory training delivered with and without coupled movement responses to the enhancement of performance on both video simulation and in-situ sport-specific tests of anticipation and batting skill. The findings are consistent with our hypotheses.

Some beneficial effects of temporal occlusion training, with and without associated movement responses, were observed that were not apparent for the control group but these benefits were selective to the anticipation of, and appropriate movement responding to, short length deliveries only. No significant facilitatory effects for temporal occlusion training were evident with respect to the anticipation of full length deliveries. These improvements of the intervention groups are consistent with hypothesis one. On the video simulation test of anticipatory skill the group that trained with a coupled movement response, but not the group that trained with the verbal response, improved after training to a level superior to that of the control group. This is an interesting observation as the video test is one that requires a conscious verbal response and is frequently characterised as a test that would primarily require a ventral stream, vision-for-perception type of processing (Müller & Abernethy, 2012). Yet superior performance was elicited through training that required a sub-conscious form of movement responding (the with-movement group), rather than a mode of responding more compatible with that of the test itself (as experienced by the without-movement group). This finding can be explained by a stronger linkage forged between perception and action due to with-movement training (or experiences), than without-movement training (or experiences), with greater transfer benefits to video (see Aglioti, Cesari, Romani & Urgesi, 2008) and in-situ tests.

On the in-situ test of batting, both with-movement and without-movement anticipatory training enhanced the capability to utilise advance information to make the appropriate foot movement to short length deliveries when vision was occluded prior to ball release. This indicates that both modes of anticipatory training have the potential to improve pick-up of advance cues, which can guide foot movements to spatially position the body for interception. This enhanced capability is valuable because, firstly, bowlers commonly use a short length ball to surprise a batsman through higher bounce height and increased ball release velocity and, secondly, pick-up of advance cues for judgement of a short length ball has been found to be a key characteristic of expert batting performance (see Müller et al., 2009). While both interventions enhanced gross body positioning, only with-movement training provided a further benefit to overall improvement in ‘good’ bat-ball contacts, indicating that opportunity for interception is a critical requirement for improvement in the complete skill. Conventional cricket practice alone over the intervention period (as experienced by the control group) did not improve body positioning or interception on the tests of anticipation. The collective findings therefore imply that there is some potential for temporal occlusion anticipatory training to supplement sports-specific practice and enhance expertise in anticipatory skill development at a rate not possible through conventional practice.

Consistent with hypothesis two, more benefits were apparent for training that involved a coupled movement response than no movement response. The with-movement training group showed superiority over the control group and pre- to post-training improvements for anticipation (on the video simulation test) and body positioning/interception (on the in-situ test) of short deliveries that were not evident for the without-movement training group. The without-movement group, however, showed similar benefits to the with-movement training group in improving the appropriateness of foot movements made in-situ to short deliveries bowled by their opponents, but no improvement was observed on the video simulation test.

These findings indicate that consistent with ecologically validity, representative task design and perception-action coupling (see Farrow & Abernethy, 2003), training that closely represents the natural performance context will maximise learning benefits on domain-specific tests, possibly due to activation of visuo-motor processes that are activated within the natural performance context. This is not to suggest that less representative training modes (without-movement training) are not valuable to learning, as evidenced by the improvement of the without-movement training group, but rather, the magnitude of learning is likely to be less.

Whilst the reported experiment has some interesting findings there are some potential limitations and difficulties to conducting research in natural settings that needs to be considered. First, temporal occlusion of vision in natural skill settings using the instrument reported in this paper presents some difficulties in creating the planned occlusion conditions. However, the created occlusion trials are highly valuable in terms of ecological validity and representative task design. Second, a perceived limitation may be that the temporal occlusion conditions of the video and in-situ tests were not the same. As mentioned earlier, the focus of the video test was to examine the capability to use advance information, whilst the focus of the in-situ test was to examine the capability to use advance and ball flight information to guide components of the striking skill. These tests were kept consistent with previous work, hence, they are highly valid measures of anticipatory skill due to their construct validity. Third, a potential limitation may be the different groups of bowlers that delivered balls to the intervention and control groups. As the velocity that balls were delivered were kept consistent across groups this ensures that all participants received similar time constraints for skill execution necessitating the use of anticipatory skill. Field-based research is clearly difficult, which can challenge experimental control, but the difficulties/limitations encountered in running this experiment can be outweighed by the importance of ecological validity and representative task design.

CONCLUSIONS

This experiment demonstrates how evidence from an expertise paradigm can be used to make less skilled individuals more 'expert like'. Both with-movement and without-movement occlusion training was successful in improving anticipatory skill, but greater improvements were found when the complete action is kept intact. Further research is required to investigate the benefits of occlusion training to quality of bat-ball contacts to full length deliveries. Here, the volume of trials and number of sessions of with-movement anticipatory training may need to be increased, whilst occlusion may need to be targeted closer to and after ball bounce to allow pick-up of late ball flight/bounce cues for fine tuning interception. Future research could improve upon the experimental design by increasing the frequency of training stimulus, as well as inclusion of transfer tests where batsmen compete against bowlers unfamiliar to them whilst their vision is temporally occluded and/or compete against bowlers unfamiliar to them in a modified match situation.

ACKNOWLEDGMENTS

This research was supported by grants from RMIT University and Murdoch University.

REFERENCES

Abernethy, B. (1981). Mechanisms of skill in cricket batting. Australian *Journal of Sports Medicine*, 13, 3–10.

Abernethy, B., Wood, J., & Parks, S. (1999). Can the anticipatory skills of experts be learned by novices? *Research Quarterly for Exercise and Sport, 70*, 313–318.

Adolphe, R. M., Vickers, J. N., & Laplante, G. (1997). The effects of training visual attention on gaze behaviour and accuracy: A pilot study. *International Journal of Sports Vision, 4*(1), 28–33.

Aglioti, S. M., Cesari, P., Romani, M., & Urgesi, C. (2008). Action anticipation and motor resonance in elite basketball players. *Nature Neuroscience*, *11*(9), 1109–1116.

Burroughs, W. A. (1984). Visual simulation training of baseball batters. *International Journal of Sports Psychology, 15,* 117–126.

Day, L. J. (1980). Anticipation in junior tennis players. In J. L. Groppel, & R. G. Sears (Eds.), *International Symposium on the Effectiveness of Teaching of Racquet Sports* (pp. 107–116). Champaign, IL: University of Illinois.

Fadde, P. (2006). Interactive video training of perceptual decision-making in the sport of baseball. *Technology, Instruction, Cognition and Learning, 4*(3–4), 265–285.

Farrow, D., & Abernethy, B. (2002). Can anticipatory skills be learned through implicit video-based perceptual training? *Journal of Sports Sciences, 20*(6), 471–485.

Farrow, D., & Abernethy, B. (2003). Do expertise and the degree of perception - Action coupling affect natural anticipatory performance? *Perception, 32*(9), 1127–1139

Farrow, D., Chivers, P., Hardingham., C., & Sachse, S. (1998). The effect of video-based perceptual training on the tennis return of serve. *International Journal of Sport Psychology, 29,* 231–242.

Haskins, M. J. (1965). Development of a response-recognition training film in tennis. *Perceptual and Motor Skills, 21,* 207–211.

Harle, S. K., & Vickers, J. N. (2001). Training quiet eye improves accuracy in the basketball free throw. *The Sport Psychologist, 15,* 289–305.

Land, M. F., & McLeod, P. (2000). From eye movements to actions: How batsmen hit the ball. *Nature Neuroscience, 3*(12), 1340–1345.

McMorris, T., & Hauxwell, B. (1995). Improving anticipation of soccer goalkeepers using video observation. In T. Reilly, J. Bangsbo, & M. Hughes (Eds.). *Science & football III* (pp. 291–294). London: E. & F. N. Spon.

Milgram, P. (1987). A spectacle-mounted crystal tachistoscope. *Behavior Research Methods, Instruments and Computers, 19*(5), 449–456.

Milner, D. A., & Goodale, M. A. (1995). *The visual brain in action.* Oxford: Oxford University Press.

Müller, S., & Abernethy, B. (2006). Batting with occluded vision: An in-situ examination of the information pick-up and interceptive skills of high and low skilled cricket batsmen. *Journal of Science and Medicine in Sport, 9,* 446–458.

Müller, S., & Abernethy, B. (2008). Validity and reliability of a simple categorical tool for the assessment of interceptive skill. *Journal of Science and Medicine in Sport, 11,* 549–552.

Müller, S., & Abernethy, B. (2012). Expert anticipatory skill in striking sports: A review and a model. *Research Quarterly for Exercise and Sport, 83*(2), 175–187.

Müller, S., Abernethy, B., & Farrow, D. (2006). How do world-class cricket batsmen anticipate a bowler's intension? *Quarterly Journal of Experimental Psychology, 59*(12), 2162–2186.

Müller, S., Abernethy, B., Reece, J., Rose, M., Eid, M., McBean, R., … Abreu, C. (2009). An in-situ examination of the timing of information pick-up for interception by cricket batsmen of different skill levels. *Psychology of Sport and Exercise, 10,* 644–652.

Osborne, K., Rudrud, E., & Zezoney, F. (1990). Improved curveball hitting through the enhancement of visual cues. *Journal of Applied Behaviour Analysis, 23*(3), 371–377.

Perneger, T. V. (1998). What's wrong with Bonferroni adjustments. *British Medical Journal, 316,* 1236–1238.

Singer, R. N., Cauraugh, J. H., Chen, D., Steinberg, G. M., Frehlich, S. G., & Wang, L. (1994). Training mental quickness in beginning/intermediate tennis players. *The Sport Psychologist, 8,* 305–318.

Starkes, J. L., & Lindley, S. (1994). Can we hasten expertise by video simulations? *Quest, 46,* 211–222.