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Developing Anticipation Skills in Tennis Using On-Court Instruction: Perception versus Perception and Action

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On-court instruction involving either Perception–action training or Perception-only training was used to improve anticipation skill in novice tennis players. A technical instruction group acted as a control. Participants' ability to anticipate an opponent's serve was assessed pre- and posttest using established on-court measures involving frame-by-frame video analysis. The perception–action and perception-only groups significantly improved their anticipatory performance from pretest to posttest. No pretest-to-posttest differences in anticipation skill were reported for the technical instruction group. The ability to anticipate an opponent's serve can be improved through on-court instruction where the relationship between key postural cues and subsequent performance is highlighted, and both practice and feedback are provided. No significant differences were observed between the perception–action and perception-only training groups, implying that either mode of training may be effective in enhancing perceptual skill in sport.

Perceptual skill is fundamental to successful performance in fast ball sports such as tennis. Skilled tennis players have to perceive and interpret the information in a quick and effective manner, thereby providing sufficient time to plan, initiate, and execute a successful return shot. An important perceptual skill is the ability to anticipate future events based on the information available in the moments leading up to ball-racket contact. A player's ability to anticipate future events quickly and accurately is particularly important during the return of serve, where the

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time required to plan and initiate a response typically exceeds ball flight time (Glencross & Cibich, 1977). Several researchers have attempted to determine the important mechanisms underpinning anticipation skill in such time-constrained situations. When compared to their less skilled counterparts, skilled tennis players: (a) are better at picking up advance (i.e., pre-event) information from an opponent's postural orientation (Williams, Ward, Knowles, & Smeeton, 2002); (b) employ more effective and efficient visual search behaviors (Goulet, Bard, & Fleury, 1989; Singer et al., 1998); (c) are more attuned to relative motion information, typically presented in the form of point-light images (Ward, Williams, & Bennett, 2002); and (d) possess greater knowledge of situational probabilities or expectational information (see Ward & Williams, 2003; Williams, Davids, & Williams, 1999).

Although knowledge of the important factors underlying anticipation skill in sport has expanded markedly in recent years, few researchers have examined whether, or how, this skill can be improved through practice and instruction. In recent reviews, Williams and colleagues (e.g., Williams & Grant, 1999; Williams & Ward, 2003; see also Abernethy, Wann, & Parks, 1998) indicated that there have been few published papers on this topic and that more systematic programs of research are required if this area of work is to make a meaningful contribution to skill enhancement in sport. These authors also concluded that interventions that develop the knowledge structures associated with anticipation skill have more practical utility in enhancing performance than clinically based training programs that focus upon improving visual function through so called 'eyerobic' exercises (e.g., see Revien, 1987). Typical interventions have involved using video simulations that recreate the performer's customary view of the action (e.g., return of serve in tennis or penalty flick in ice hockey). These film sequences are presented to the learner either in 'real time' or using slow motion and are coupled with the directive to focus attention on the most informative cues. The most important cues or clues are usually derived from a number of sources including a review of related literature in the sport, reference data on the visual search behaviors employed by skilled performers gathered using eye movement registration systems, verbal report protocols, or questionnaires (for a review of available methodologies, see Cauraugh & Janelle, 2002; Williams et al., 1999).The relationship between these key sources of information and subsequent action requirements is highlighted and feedback about the correct response provided (e.g., see Abernethy, Wood, & Parks, 1999; Scott, Scott, & Howe, 1998; Singer et al., 1994).

Despite the obvious potential of this form of instruction, much of the existing research is plagued by shortcomings, preventing a clear evaluation of its usefulness. The majority of researchers have failed to employ control groups who, for example, receive no training or only technical instruction on stroke execution, in addition to the conventional perceptual training group. The observed improvements in performance may therefore be due to conformation bias or increased familiarity with the test environment rather than any meaningful treatment effect (e.g., see Christina, Barresi, & Shaffner, 1990; Singer et al., 1994). Researchers have also neglected to employ suitable transfer tests to examine whether training facilitated performance in a real world context (e.g., see Farrow, Chivers, Hardingham, & Sachse, 1998; McMorris & Hauxwell, 1997; Williams & Burwitz, 1993). The design and implementation of some measure of transfer is essential to determine whether any improvements observed in the laboratory setting transfer back to the game situation.

Williams and colleagues (i.e., Williams, Ward, & Chapman, 2002; Williams, Ward, Knowles et al., 2002) addressed a number of these difficulties in two recent studies involving tennis forehand and backhand passing shots and the penalty-flick in field hockey. Field- and laboratory-based measures of anticipatory performance were employed. The laboratory-based anticipation tests required participants to respond in an interceptive manner to near 'life-size' film images of an opponent performing tennis passing shots or the hockey penalty-flick. In the field-based scenarios participants had to physically respond to actual tennis shots or penalty-flicks on the tennis court and hockey pitch, respectively. Split-screen, digital video analysis was employed to measure the initiation of movement, by for example the hockey goalkeeper, relative to the moment of racket- or stick-ball contact by her opponent in field and laboratory settings. In both studies, participants who were exposed to perceptual training that involved video simulation, instruction as to the key postural cues underlying anticipation skill, and feedback, showed greater improvements in anticipatory performance on laboratory- and field-based tests when compared with matched-ability control (i.e., completed pre- and posttests only) and technical instruction (i.e., instruction focusing on technical skill development only) groups. The improvement in performance observed for participants undertaking perceptual training in these experiments was a meaningful training effect as opposed to the result of increased test familiarity or confirmation bias and, perhaps most importantly, this improvement transferred from the laboratory to the field setting.

Although several researchers have coupled video simulation with on-court training (e.g., Harle & Vickers, 2001; Singer et al., 1994; Williams, Ward, & Chapman, 2002; Williams, Ward, Knowles et al., 2002), there have been very few in vivo studies. In one recent exception, Adolphe, Vickers, and LaPlante (1997) required elite volleyball players to participate in a 6-week perceptual training program designed to improve visual search behaviors and performance accuracy in passing to the area occupied by the setter. The intervention included video feedback on gaze behavior and on-court sessions to improve ball detection, tracking, and forearm passing skills. Significant pre to posttest improvements were found in tracking onset, tracking duration, and the ability to maintain a stable gaze on the contact point during step corrections. A three-year follow-up was undertaken based on their serve reception performance scores over this period. Those players who participated in the perceptual training program showed much higher performance levels compared to a matched group of players who had not undergone such training, although it could be argued that several other factors may have contributed to the observed improvement. Thus far, no researchers have examined the relative effectiveness of video- and field-based practices and, given the practical significance of this issue, further investigation is merited.

A related question is to what extent should we maintain the close functional links between perceptual and physical (action) variables during practice and performance. Historically, researchers have not emphasized the importance of maintaining links between perception and action during performance testing (i.e., the so called 'limiting principle'; see Marteinuk, 1976) or learning. However, one of the key aims of simulation research examining perceptual-cognitive and perceptual-motor tasks outside of the sport domain has been to increase the 'fidelity' of the training environment to enhance both ecological validity and the likelihood that learning will occur (see Jacobs & Dempsey, 1993). Several authors (e.g., E. Gibson, 1969; J. Gibson, 1979; Michaels & Carello, 1981) have argued that the discovery of multimodal invariants is required for skilled action and that training should try and map these invariant properties on to corresponding physical (action) variables. A possible implication is that the multi-sensory learning environment should be maintained by presenting visual, tactile, and auditory information and that the close functional coupling between perception and action should be preserved by requiring the learner to physically respond to the action. According to this perspective, training visual-perceptual aspects of performance in isolation from the movement aspect of performance may be ineffective given the importance of maintaining the linkage between perception and action.

Milner and Goodale (e.g., Goodale & Milner, 1992; Milner, 1998; Milner & Goodale, 1995) argued that different functional streams of processing sub-serve perception and action. The ventral stream that runs from the striate cortex to the inferotemporal region is presumed to be crucial to the visual perception and identification of objects, whereas the dorsal stream that runs from the striate cortex to the posterior parietal lobe is responsible for the visual control of action. An implication may be that perceptual training should be specific to the functional demands placed upon the visual system in the performance context. Simulations that require the learner to physically respond to the action in a manner synonymous with actual performance may train both ventral and dorsal processes, whereas those that merely require the learner to recognize the relevant event may only be effective in training processes sub-served by the ventral stream. It may be, for example, that video simulations place greater emphasis on the ventral stream, whilst virtual environments, simulators and field-based practices, are able to effectively train both the ventral and dorsal routes (Williams & Grant, 1999). Clearly, research is needed to determine whether training simulations that require learners to physically respond to the action sequences are more effective in terms of enhancing real-world performance than those based merely on judgment.

In this study we examined whether novice tennis players could be trained to anticipate an opponent's serve using various forms of on-court instruction and practice. In particular, the intention was to investigate whether perceptual training that required the learner to physically respond to the action by attempting to return the serve was more effective than training that merely required the learner to anticipate the opponent's intentions. A group of participants that received technical instruction as to how to play forehand and backhand returns was included as a control. We assessed anticipatory performance pre and posttest using established on-court measures. It was hypothesized that the two perceptual training groups would improve their performance from pre- to posttest compared with the technical instruction control group, whilst the perception-action group was expected to demonstrate a more marked improvement in performance compared with the perceptual training group.

METHOD

Participants

Twenty-four males (M age $= 21.7$, $SD = 1.5$ years of age) volunteered to participate in the experiment. The participants were novice tennis players who had played the sport on a recreational level only for an average of 3.5 years ($SD = 1.2$). The participants provided informed consent prior to taking part in the experiment and were treated in accordance with the "Ethical Principles of Psychologists and Code of Conduct" (American Psychological Association, 1992).

Task and Procedure

Participants were tested on an indoor court using standard tennis balls and rackets. The task required participants to attempt to return a total of 20 serves delivered by two county level tennis players. The two servers, who performed a block of 10 serves each, were informed to serve the ball using their regular action to the right and left sides of the service box with a relatively consistent ball velocity in the range of 70–90 km$\cdot$h^{-1}. A tripod-mounted radar gun (JUGS doppler, Decatur Electronics, Decatur, Illinois) was employed to monitor ball velocity. Those serves where the ball velocity was outside of this range or that struck the net, landed outside the service box, or were hit into the middle of the service box were repeated. Serves that landed in the middle of the service court were eliminated, because it was difficult to classify objectively a player's response to such serves. Altogether, 30% of trials were repeated. The order in which the two servers performed their respective block of 10 trials was counter-balanced across groups and test conditions. The servers were not aware of the purpose of the research work or the type of instructional training undertaken by each participant. The participant, located on the baseline next to the right-hand service box, was required to return each serve as in a match situation.

The participants' actions were recorded using a digital video camera (JVC GR-DVL 9600, Tokyo, Japan). The camera was positioned behind and slightly to the right of each participant so that the server and participants' actions were clearly visible within its field of view for subsequent analysis. A similar procedure was employed successfully to differentiate skilled from less skilled performers in a previous analysis of anticipation skill involving tennis forehand and backhand strokes (see Williams, Ward, Knowles, et al., 2002). To simplify the analysis process, participants were asked to move to their right or left side only in response to each serve rather than in a forward direction. The experimental set-up is presented in Figure 1. A total of three familiarization trials were provided prior to each block of 10 test trials. An inter-trial interval of approximately 10 s was employed. The test session took approximately 15–20 min to complete.

Training Protocol

Participants were divided randomly into three groups of equal ability based on their scores on the pretest. A posttest was completed one week after the pretest for each participant. The

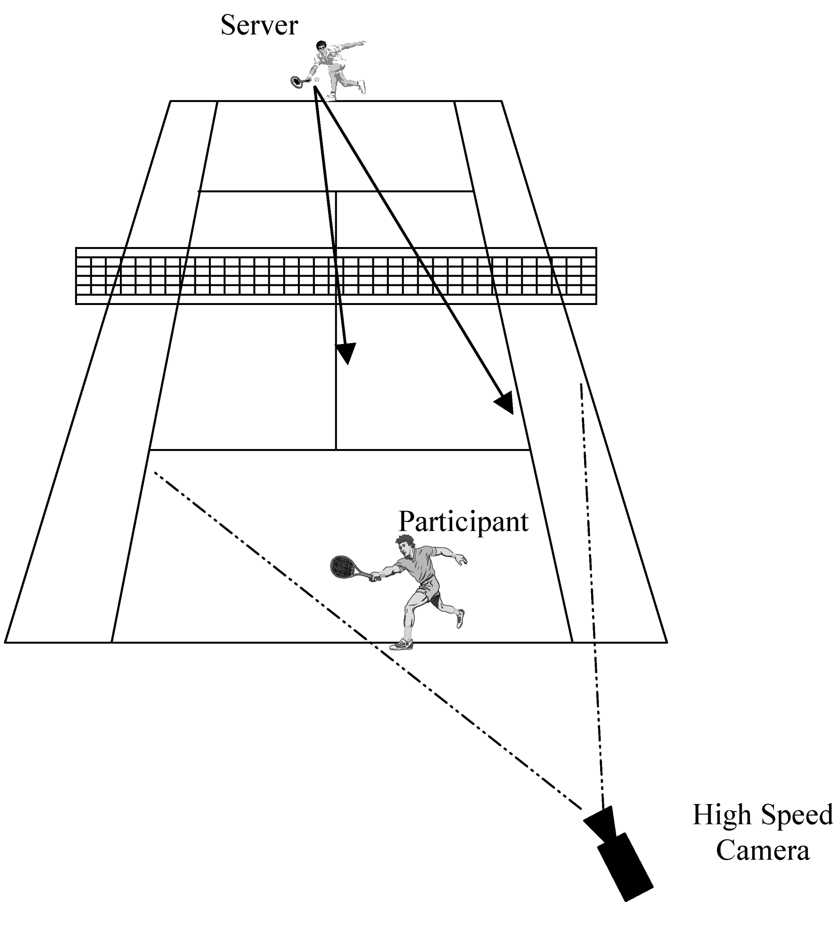

Figure 1. The experimental layout employed in the on-court anticipation test.

participants underwent one of three different types of training interventions in the time period between the two test sessions. A county level tennis player and Lawn Tennis Association (UK) certified tennis coach was employed to deliver each instruction program. The instructor was not involved in the pre and posttest sessions and was not aware of the specific theoretical predictions under investigation. The coach was informed to be consistent in the level and frequency of instruction provided to participants. Instruction was generally provided on the majority of trials early in practice, but an attempt was made to 'fade out' the learners' dependence on prescriptive guidance as practiced progressed. A question and answer mode of instruction was also employed periodically to ensure that the learners were aware of the information that they should be focusing upon.

Perception–Action Training Group

The Perception–Action group ($n = 8$) received 45 min of on-court training to improve anticipation skill. The structure of the on-court instruction followed the guidelines proposed by Abernethy et al. (1999) and Singer et al. (1994). This training included formal instruction on the biomechanics of the tennis serve, emphasizing the proximal-to-distal progression of stroke kinematics (5 min). The key information cues underlying anticipation skill were highlighted to demonstrate the linkage between a particular cue and the subsequent response requirements (20 min). The main information cues highlighted were derived from published research where various techniques have been employed to identify the important sources of information employed by skilled tennis players to anticipate a server's actions (for more specific information regarding the cues highlighted, see Cauraugh & Janelle, 2002; Goulet et al., 1989; Singer, Cauraugh, Chen, Steinberg, & Frehlich, 1996; Singer et al., 1998). Participants were then given the opportunity to practice anticipating and physically returning an opponent's serve (20 min). This training protocol gave participants the opportunity to further refine potential couplings between perception and action variables.

Perception-Only Training Group

Participants in the Perception-only training group ($n = 8$) followed a training program similar to that highlighted for the Perception–Action group. The only difference between the training interventions was that during the final 20 minutes of practice, participants were not allowed to physically move to intercept the ball. The participants were merely required to indicate verbally whether the ball was likely to be served to their "right" or "left" side. No physical action was required.

Technical Instruction Group

Participants in the Technical instruction group ($n = 8$) were given formal instruction on the biomechanics of the tennis serve, emphasizing the proximal-to-distal progression of stroke kinematics (5 min). The participants were then given specific technical instruction as to how to play forehand and backhand returns (20 min). Finally, the participants physically practiced returning a variety of different types of serve (20 min). No instruction as to the important visual cues underlying anticipation skill was provided. The intention in this intervention was to provide an expectancy set for training benefits that was comparable to that of the perception-action and perception only training groups.

Dependent Measures and Statistical Analysis

Two measures of anticipatory performance were obtained following frame-by-frame analysis of the video data at a sampling frequency of 50 Hz. The two dependent measures were:

Response Initiation Time

The response initiation time (RT) was defined as the mean time period from the moment the ball left the server's hand to the initiation of the participant's first step to the right or left hand side of the service court (in ms).

Response Accuracy

Response accuracy (RA) is the mean accuracy of response (i.e., movement to the left or right side) relative to the ball's landing position on the right or left side of the service area. This measure was calculated as a proportion of the number of trials presented (in %).

No attempt was made to determine the accuracy of the return stroke or technical aspects of the skill. Our intention was to specifically determine whether any improvements were apparent in the participants' ability to anticipate the ball's likely destination quickly and accurately, rather than more strategic aspects of performance (e.g., decision-making skill) or motor proficiency (e.g., technical ability).

Inter-observer reliability for the RT variable was determined by calculating the intra-class correlation and the limits of agreement for a sample of 20 trials selected at random from the pretest (see Atkinson & Nevill, 1998; Bland & Altman, 1999). The limits of agreement represent the systematic bias, the general tendency for the scores to differ between observers, and the random error between the two observers. The mean of the differences is represented by the systematic bias and 1.96 standard deviations of the differences provide an indication of the random error.

The performance data were analyzed using factorial MANOVA in which Group (Perception–action, Perception-only, Technical) was the between-participants variable, Test (pre-, post-) the within-participants variable, and RT and RA the dependent measures. Significant effects were followed up using discriminant analysis as recommended by Field (2000), univariate analysis of variance (ANOVA), and Scheffé posthoc tests, as appropriate. Effect size calculations were based on the Cohen's *d* statistic.

RESULTS

The mean performance scores are highlighted in Table 1. The main effect for group was not significant, Wilks' lambda = .64, $F(4, 40) = 2.45$, $p = .06$. However, significant effects were observed for test, Wilks' lambda = .18, $F(2, 20) = 44.84$, $p < .01$, and the Group × Test interaction, Wilks' lambda = .36, $F(4, 40) = 6.57$, $p < .01$. Separate univariate analysis of the two dependent variables showed a significant effect for RT, $F(2, 21) = 94.17$, $\omega^2 = .74$, $p < .01$, but not for RA, $F(2, 21) = 1.07$, $\omega^2 = .04$, $p > .05$. Univariate analysis of the

Table 1
Mean Performance Scores and Standard Deviations on the Pre- and Posttests for the Three Groups of Participants

		Pretest		Posttest	
Group		RT (ms)	RA (%)	RT (ms)	RA (%)
Perception–action training	*M*	1437.8	89.4	998.6	84.3
	SD	72.1	4.2	192.5	9.79
Perception-only training	*M*	1492.5	90.0	1163.9	87.5
	SD	72.6	11.0	179.6	5.9
Technical training	*M*	1402.7	90.0	1360.7	91.3
	SD	67.6	13.4	84.6	13.5

Group × Test interaction indicated a significant effect for the RT variable, $F(2, 21) = 18.11$, $\omega^2 = .14$, $p < .01$, but not for RA, $F(2, 21) = .82$, $\omega^2 = .02$, $p > .05$. Only one significant discriminant function was identified, χ^2 (4) = 25.602, $p < .001$, with RT being the only variable to contribute to the model. The squared canonical correlation (r^2) was 0.66. The negative and positive contribution of the standardized canonical discriminant function coefficients for pre ($\beta = -.873$) and post RT ($\beta = 1.131$) respectively, suggest that group separation was determined by the difference between these two variables. The structure matrix also confirmed that the post RT (.671) had the largest absolute correlation with the significant discriminant function and could be considered the greatest contributor to the model when compared to pre RT (−.276). Moreover, the functions at group centroids indicated the differences in post RT were largely a consequence of the difference between the two experimental groups (−1.166, −.688) and the technical instruction group (1.834). In total, the model was capable of predicting 75% of group membership. All members of the technical instruction group were accurately classified whereas the participants in the experimental groups were classified in either of the perception-action or perception only groups.

Post hoc tests on the RT variable revealed that, while there were no significant differences between the three groups on the pretest, both the perception-action ($p < .01$, $d = 2.44$) and perception only training ($p < .01$, $d = 1.40$) groups recorded faster RT values than the technical training group on the posttest. The perception-action ($p < .01$, $d = 3.0$) and perception only training groups ($p < .01$, $d = 2.4$) significantly reduced their RT scores on the posttest compared with the pre-test, whereas there was no significant pre to posttest difference for the technical training group ($p > .05$, $d = .54$). No significant differences were observed between the perception-action and perception only training groups on the posttest ($p = .07$, $d = .88$).

The Bland-Altman method revealed that the systematic bias was very low (7 ms) as was the random error (78 ms), with 95% of the differences between the two observers lying between 85 ms and −71 ms. The intra-class correlation between the two observers was also very high, 0.96. These limits suggest that the observed performance differences were not attributable to inter-individual variability in data coding.

DISCUSSION

The intention in this study was to investigate whether novice tennis players could be trained to anticipate an opponent's serve using various forms of on-court instruction and practice. Another aim was to examine whether perceptual training that required the learner to physically respond to the action by attempting to return the serve was more effective than training that merely required the learner to try and anticipate the opponent's intentions, with no physical action required. It was hypothesized that the two perceptual training groups would improve their performance on the posttest compared with the technical instruction group, whilst the perception-action group was expected to demonstrate a more marked improvement in performance compared with the perception only training group.

The perception-action ($d = 2.44$) and perception only ($d = 1.40$) training groups significantly reduced their RT scores from pre to posttest, compared with the technical instruction group ($d = .54$). The mean improvement in RT from pre to posttest for the perception-action and perception only groups was 383.9 ms compared with 42.0 ms for the technical training control group. The reduction in RT for the two perceptual training groups reflects a meaningful improvement in anticipatory performance rather than the result of increased test familiarity or confirmation bias. Findings provide support for other researchers who have enhanced anticipation skill in sport using either video simulation (e.g., Abernethy et al., 1999) or a combination of video simulation and on-court instruction (Singer et al., 1994; Williams, Ward, & Chapman, 2002; Williams, Ward, Knowles et al., 2002). Moreover, this study suggests that anticipation skill can be improved in a group of novice tennis players following a mere 45 min of on-court instruction and training (cf. Williams, Ward, Knowles, et al., 2002).

As reported by several researchers, no significant differences were observed between or within groups for the RA variable (e.g., Farrow et al., 1998; Williams,Ward, & Chapman, 2002; Williams, Ward, Knowles et al., 2002). It appears that participants only initiate a response in such situations when the probability of success is very high (cf. Alain & Proteau, 1980). With increasing skill, this level of confidence is reached much earlier in the viewing process with players relying on pre-event (i.e., ball-racket contact) information as opposed to early ball flight characteristics. Perceptual training appears to enhance the performer's ability to pick up these subtle postural cues earlier in the viewing process, whilst at the same time maintaining the same level of response accuracy (Goldstone, 1998). The more skilled performers' ability to rely on sources of information that appear earlier in the action compared to that employed by less skilled counterparts has also been demonstrated by other researchers (e.g., Abernethy et al., 1999), with this ability being due, at least in part, to greater attunement to relative motion information (Ward et al., 2002).

No significant differences in performance were observed between the perception-action and perception only training groups on the pre or posttest. Anticipation skill can be improved through appropriate instruction regardless of whether the learner has to physically respond to the action or merely make a perceptual judgement as to the likely destination of an opponent's serve. If, as proposed by Milner and Goodale (e.g., 1995), different functional streams of processing sub-serve perception and action, it may be that perceptual training should be specific to the functional demands placed upon the visual system in the performance context. The process of reading an opponent's intentions based on postural cues is likely to rely more on ventral rather than dorsal processes and consequently, these perceptual skills may be trained without the learner having to physical respond to the action.

An interesting issue is whether similar results would be observed if the execution of the return stroke was assessed in conjunction with an evaluation of the accuracy of the learner's perceptual judgments. In this situation the role of the dorsal stream might be more fully assessed and consequently, the learner might have benefited from the additional requirement of having to map relevant perceptual variables onto action components as proposed by Gibson (1969) and others (e.g., Gibson, 1979; Michaels & Carello, 1981). The key point is that the specific role played by each processing stream is constrained by what the performers intend to do with the information that is picked up (Keil & Bennett, 2002).

These findings could have important implications for those interested in developing perceptual skill in sport. In particular, if anticipation skill can be improved equally as effectively with or without the requirements of having to move in response to the action, coaches can make informed choices as to how best to utilize practice time. For example, in certain situations such as when a player is injured or fatigued video stimuli coupled with a verbal or pen-and-paper response may be more appropriate than physical practice, whereas at other times practice time should be spent on the tennis court with the performer being required to move in response to the action. Further investigation is required to determine whether, and under what circumstances, perception only training may be more effective than perception-action training and vice versa.

The nature of the task may also play an important role in determining the effectiveness of various forms of perceptual training. It may be that perception only training is at least as effective as perception-action training when the task emphasizes judgment or object identification such as, for example, the reading of postural cues in tennis or the recognition of patterns of play in team sports (e.g., see Williams & Davids, 1995). Alternatively, perception-action training may offer an advantage in situations where perceptual variables (e.g., optic variables) need to be mapped directly onto various action parameters (e.g., timing and force of stroke production) such as, for example, when catching or striking a ball with a racket. In this latter scenario, perception and action would appear to be closely coupled such that performers have to continually adjust the spatial and temporal characteristics of the effector to ensure successful interception (i.e., perception for action rather than identification). In contrast, the process of perceiving the direction of an opponent's pass in soccer may be somewhat divorced from the ensuing response with the player deciding to move to pick up another opponent rather than to intercept the ball's flight path (i.e., perception for identification more than action). Clearly, such issues provide potentially fruitful areas of investigation for those interested in enhancing perceptual skill in sport.

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