Time course of attention and decision making during a volleyball setting task

By: Benjamin A. Sibley and Jennifer L. Etnier

Sibley, B.A., & Etnier, J.L. (2004). Time course of attention and decision-making during a volleyball setting task. *Research Quarterly for Exercise and Sport, 75,* 102-106.

This is an Accepted Manuscript of an article published by Taylor & Francis in *Research Quarterly for Exercise and Sport* on 01 March 2004, available online: http://www.tandfonline.com/10.1080/02701367.2004.10609138

Abstract:

Attention is a term that has been used to describe a broad range of topics in the sport and exercise literature (Nougier, Stein, & Bonnel, 1991). Research focusing on attention has included studies on selectivity, concentration, mental set, visual search, arousal, and information processing (Abernethy, 2001), and a variety of techniques (e.g., occlusion methods, eye-tracking tasks, dual-task paradigms) have been used to examine the attention-related behaviors of participants during sport task performance. Many studies in sport have used occlusion and eye-tracking techniques to assess the orientation of visual attention during ball-tracking tasks (Land & McLeod, 2000; Ripoll & Fleurance, 1988; Singer et al., 1998; Whiting, 1968, 1970; Whiting, Alderson, & Sanderson, 1973; Whiting & Sharp, 1974). The findings of this research has shown that performers do not need to track the entire ball flight but rather that skilled sport participants track the initial flight of the ball, and then their eyes "shoot ahead" to the final portion of flight.

Keywords: dual-task paradigm | sports performance

Article:

Attention is a term that has been used to describe a broad range of topics in the sport and exercise literature (Nougier, Stein, & Bonnel, 1991). Research focusing on attention has included studies on selectivity, concentration, mental set, visual search, arousal, and information processing (Abernethy, 2001), and a variety of techniques (e.g., occlusion methods, eye-tracking tasks, dual-task paradigms) have been used to examine the attention-related behaviors of participants during sport task performance. Many studies in sport have used occlusion and eye-tracking techniques to assess the orientation of visual attention during ball-tracking tasks (Land & McLeod, 2000; Ripoll & Fleurance, 1988; Singer et al., 1998; Whiting, 1968, 1970; Whiting, Alderson, & Sanderson, 1973; Whiting & Sharp, 1974). The findings of this research has shown that performers do not need to track the entire ball flight but rather that skilled sport participants track the initial flight of the ball, and then their eyes "shoot ahead" to the final portion of flight.

However, there is a "theoretical distinction...between the orientation of attention ... and the distribution of attentional resources" (Nougier et al., 1991, p. 308). Nougier and Rossi (1999) suggested that the "orienting of visual attention ... can be viewed as a controlling process which modulates information processing at different levels" (p. 247). This distribution of attentional resources, or information processing, is of primary interest in this study. The concept of limited attentional capacity (Nougier et al., 1991) has guided research on the distribution of attentional resources. Information processing research is of particular interest in real-world sports, as there are often situations in which multiple stimuli must be processed simultaneously. If the information processing system is overloaded, it can lead to a decrement in performance. There are several variations on this limited capacity concept (Kerr, 1973; Posner& Keele, 1969); however, the basic assumption is that different operations, or tasks, will demand varying degrees of the limited processing capacity and that the simultaneous performance of tasks can strain this limited capacity. This basic assumption allows us to make inferences about the relative attentional demand of certain tasks.

The dual-task paradigm was developed to assess the amount of attention, or central processing space, devoted to a task at a given time. In a dual-task paradigm, participants complete a primary and secondary task individually and then simultaneously. Performance on the secondary task (typically a simple reaction time task) is used to derive the attentional demand of the primary task (Abernethy, 2001) .A greater attention demand by the primary task will take up more central processing space, which will be reflected in decreased performance on the secondary task. Research that has used a dual-task paradigm to assess information processing during the performance of real-world sport skills is sparse. However, the limited research that exists has focused on identifying the time course of attention in different skills and the impact of task difficulty on attentional demands (Castiello & Umilta, 1988; Prezuhy & Etnier, 2001; Rose & Christina, 1990).

Decision making is an aspect of task difficulty that has not yet been examined with regards to its impact on attentional demands during sport skill performance. During real-world sport performances, athletes not only have to perform motor tasks but they also need to make decisions about when, where, and in what direction to perform the tasks. These decisions may take a toll on the attentional resources available to the athlete, thereby affecting performance. Therefore, it would be useful to gain a better understanding of the relationship between decision making, attention demands, and performance.

The present study adds to the existing literature on attention in two ways. First, we examine the pattern of attention demands in a previously unstudied motor task—the volleyball set. This task involves both a ball-tracking component (following the flight of the ball) and a projection-striking component (accurately setting the ball to a target), making it similar to tasks studied previously (service returns in tennis and volleyball). However, the ball-tracking component of this task is different from previously studied tasks in that the ball follows a "soft," relatively predictable parabolic arc to the setter. Second, we examine the impact of decision making on the attention demands and task performance. Specifically, information will be gained relative to whether or not (a) a choice about where to set the ball increases the attentional demands of the task and (b) a decision-making paradigm can influence the accuracy of setting performance.

Attentional time course was studied during two volleyball tasks: simple setting (forward, backward) and choice setting (in which the participant had to decide between a forward or a backward set based a cue given during the skill). Attention demands were measured at different discrete time points from the time the ball was tossed to the participant to the time of contact with the ball. Hypotheses were based on the previous literature in which a dual-task paradigm had been used to study attentional capacity during reception of a ball (Castiello & Umilta, 1988). It was hypothesized that attention demands would be highest at initiating the toss to the participant, during the visual search for the ball, and as initial information was gathered on the speed and direction of the ball. It was further hypothesized that there would be an increase in attention demands immediately prior to ball contact as final adjustments were being made. Thus, the overall pattern of attention was expected to be a U-shape, with the highest attentional demands at the beginning and end of the task and with lower demands in the middle of the ball's flight toward the participant. It was also hypothesized that attention demands would be higher during performance of choice setting as compared to performance of simple setting. Finally, it was hypothesized that there would be a performance decrease on the primary task during the choice setting as compared to the simple setting, because the attentional demand devoted to making the decision would decrease the amount of attention available to focus on the actual set.

Method

Participants

Twenty intermediate-level volleyball players (12 women, 8 men) were recruited from undergraduate exercise science classes at Arizona State University. Participants were required to have had at least 1 year of organized volleyball experience and to be currently playing on teams competing at a recreational level or higher. Organized volleyball was defined a priori as high school varsity, college club, college varsity, or professional. All participants in this study had played at the high school or college club level, with none playing at or above the college varsity level. The average age of the participants was 21.7 years *(SD* = 3.31), and the average total years of participation in volleyball was 6.95 years *(SD* = 3.65). While this sample included a fairly broad range of expertise levels, all participants were above novice level, but none had competed at what would be considered an "elite" level of play.

Primary Task

The primary task was a two-handed overhead volleyball set. Participants stood at the net at the center of the volleyball court. They received an underhand-tossed ball from approximately 20 feet (6 m) away and performed either a front or a back set. The direction of the set was determined by the color of the ball. A white ball indicated a front set, while a blue-and-white striped ball indicated a back set. The ball tosser stood behind a 5-foot (1.52-m) high barrier so that the participant could not determine the color until the ball was in flight. This ball color method of determining set-type was used to minimize structural interference with the auditory reaction time test and because, in game situations, setters may rely on visual cues when deciding where to set the ball.

An ecologically valid performance measure was difficult to develop because of the nature of the volleyball set. A good set needs to target a specific point and have a high arch. Therefore, simply placing a target on a wall or on the floor would not be an accurate measure of the quality of the set. In this experiment, a 36-inch (.91-m) diameter hoop was placed 12 feet (3.66 m) from the participant at net height, parallel to the ground. Participants were instructed to set the volleyball through the hoop. Sets were scored as going through the hoop, hitting the hoop, near misses (within one ball diameter of the hoop) or complete misses, and assigned point values of 3, 2,1, or 0, respectively. Points were then totaled within blocks of trials to create a composite score.

Secondary Task

The secondary task was an auditory reaction time (RT) test. During the primary task performance, an auditory tone was administered via a small speaker near the performer. The participant then had to respond to the tone by yelling "ball" as quickly as possible. The participant wore a radio headset with a microphone that detected the response and sent a signal to a voice-activated relay and timing mechanism. RT was measured as time from the tone to the participant's first auditory response.

Tones were manually administered at four different probe positions during the primary skill. Probe positions were designed to tap attentional demands at the beginning (PP1), middle (PP2, PP3), and end (PP4) of the ball's flight to the participant. The four probe positions used were: (a) as the ball was tossed (PP1), (b) just prior to the peak of the toss (PP2), (c) just after the peak of the toss (PP3), and (d) just prior to the ball touching the participant's hands (PP4). Catch trials, in which no tone was given, were also included to eliminate anticipation. Due to the variable nature of the tosses, a timer- or computer-controlled administration of the tones could not be used; therefore, an experimenter administered the tones manually. To ensure that the presentation of the probes was compatible with their descriptions, 160 trials were videotaped and analyzed using frame-by-frame (30 Hz) analysis. Results indicated that the mean total ball flight was 1,440 ms and that the mean peak of the ball flight occurred at 868 ms. On average, probe administration occurred for PP1 at 299 ms (SD = 100 ms), for PP2 at 606 ms (SD= 141 ms), for PP3 at 997 ms (SD= 121 ms), and for PP4 at 1,315 ms (SD= 159 ms). Thus, the probe positions were confirmed to correspond to their operational definitions. That is, PP1 was at the beginning of the ball flight, PP2 and PP3 were in the middle of the ball flight, and PP4 was at the end of the ball flight. In addition, results of an analysis of variance (ANOVA) revealed a significant main effect for probe position, $F(4) = 635.27$, $p < .001$, and a Tukey's b post hoc analysis showed that probe administration occurred at four significantly different time points, $p < .05$.

Procedure

On arrival, participants were asked to complete a letter of consent approved by the university's Institutional Review Board and a brief questionnaire about their volleyball experience. They were then given time to warm up and practice setting at the targets. This practice time was to accustom the participants to the targets to minimize any learning effect during the experimental trials.

To ensure that the basic assumptions of a dual-task paradigm were met (see Abernethy, 2001), baseline measures for both the primary and secondary tasks were taken independently of each other. Following baseline measures, a rest period of 5 min was offered. Experimental trials were then administered. A block of 20 front sets, a block of 20 back sets, and 2 blocks of 20 choice sets were performed. The order in which these blocks were presented was randomized among participants. Within each block of 20, four tones at each point of the four probe positions and four catch trials were presented in a random fashion.

Statistical Analyses

Separate analyses were performed to ensure that the assumptions for a dual-task paradigm were met. Results from these analyses indicated that the setting task was maintained as the primary task and performing the two tasks simultaneously was attentionally demanding. For more information on these analyses, please contact the primary author.

To examine the time course of attentional demands relative to the difficulty level of the task and set direction, RT was examined using a Task Difficulty (simple, choice) x Set Direction (front, back) x Probe Position (PP1, PP2, PP3, PP4) 2 x 2 x 4 RM ANOVA with repeated measures on all factors. To examine the effect of decision making on setting performance, a Wilcoxon Signed ranks test was performed to compare performance during simple setting with that during choice setting.

For all RM analyses, the Huynh-Feldt epsilon was examined to check the assumption of sphericity. When the assumption was violated (i.e., $\varepsilon < .75$), multivariate tests of significance were used. When significant interactions were found, simple ANOVAs and pairwise comparisons were used to delineate the nature of these interactions. For all significant effects, partial η^2 values were reported to indicate meaningfulness.

Results

Time Course of Attention

Means and standard deviations for RT are presented in Table 1. There were significant main effects for task difficulty, $F(1, 19) = 15.89$, $p < .001$, $\eta^2 = 0.46$, and probe position, $F(3, 57) = 25.07$, $p < .001$, $\eta^2 = 0.57$. However, these main effects were superceded by the Task Difficulty x Probe Position interaction, $F(3, 57) = 3.03$, $p < .05$, $\eta^2 = 0.14$, which indicated that the patterns of attentional demand for the simple and choice tasks were different from one another (see Figure 1). Post hoc analyses indicated significant differences in RT between simple and choice sets at PP1 and PP2. Differences in RT were not significant at PP3 or PP4. Simple effects for probe position were also tested separately at each level of task difficulty. There was a significant effect for probe position on the simple sets, $F(3, 57) = 13.36$, $p < .001$, $\eta^2 = 0.41$, as well as on the choice sets, $F(3, 57) = 24.12$, $p < .001$, $\eta^2 = 0.46$. Pairwise comparisons indicated that for simple sets, RT at PP1 was significantly greater than RT at PP2, at PP3, and at PP4, and that RT at PP4 was significantly greater than RT at PP3. However, for choice sets, pairwise comparisons showed that RT at PP1 was greater than RT at PP2, at PP3, and at PP4, but that no other significant differences for probe position existed.

Table 1. Mean probe position reaction time as a function of set complexity and direction (ms)

	PP1		PP2		PP3		PP4	
Set type	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Simple sets								
Front	543	127	468	93	479	82	495	90
Back	555	113	467	112	460	77	509	90
Main effect	549	115	468	100	469	72	502	79
Choice sets								
Front	576	90	488	100	496	94	498	90
Back	603	131	494	92	491	99	494	87
Main effect	590	107	491	97	494	91	496	83

Note. M = mean; *SD* = standard deviation.

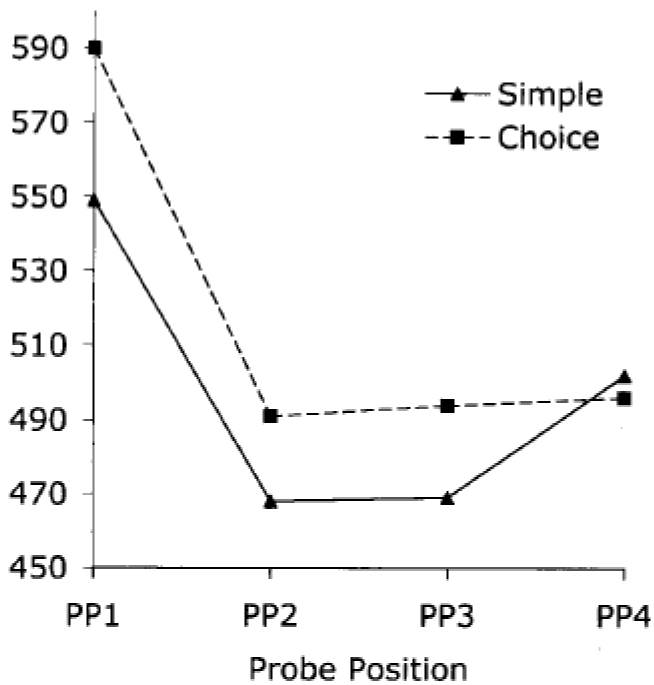

Figure 1. Time course of attention for simple and decision-making volleyball sets.

Performance of the Primary Task

The Wilcoxon Signed Ranks test indicated that setting performance was significantly more accurate, $z = -2.49$, $p < .05$, for the simple setting task ($M = 26.78$, $SD = 6.85$) than for the choice setting task ($M = 23.53$, $SD = 7.50$). The sum of the positive ranks ($n = 16$) was 171.5, and the sum of the negative ranks ($n = 4$) was 38.5.

Discussion

The purpose of this study was to examine the time course of attention during a volleyball set and the impact of a simple decision-making paradigm on both attention and task performance. The hypothesis, that the decision-making paradigm would increase the attentional demand of the task, was supported. Compared to the simple sets, attentional demand was higher on the choice sets at the first two probe positions. This suggests that choosing the direction to set the ball and preprogramming the motor portion of the task affected attention during the first half of the ball's flight.

The hypothesis regarding the time course of attentional demands was supported for the simple setting task. As expected, the greatest attentional demand was during the initial portion of the ball's flight. This finding is consistent with suggestions made in the eye-tracking literature that attentional resources during this phase of ball flight are dedicated to gathering the information (speed and direction of the ball) needed to intercept it (Ripoll & Fleurance, 1988). The findings of this study show that the overall demand on underlying attentional resources reflects this selective visual attention. The finding that reaction times were faster at PP2 and PP3, indicating lowered attentional demand at these time points, is also consistent with previous research findings that individuals do not need to visually track the middle portions of ball flight (Ripoll & Fleurance, 1988; Singer et al., 1998).

The hypothesized increase in attentional demand during the last portion of ball flight was also supported. On simple sets with the predetermined target, relative to PP3, there was a significant increase in attentional demands at PP4. Consistent with the conclusions of Prezuhy and Etnier (2001), this increase in attentional demand likely occurred as the participant processed proprioceptive information and made accuracy adjustments during ball contact. The processing of peripheral vision information of the hands may also contribute to the increased attentional demand at this time point (Davids, 1988).

The final hypothesis, that the addition of the decision-making requirements would negatively affect setting accuracy, was also supported. There was a small but significant decrease in setting performance when the participants were forced to choose their set direction. As stated earlier, there was also an increased attentional demand associated with the decision-making paradigm. Therefore, executing a motor skill and decision complexity may make an impact on one another. Making several decisions simultaneously or decisions that require the processing of multiple stimuli-situations common in real sport environments-may seriously impact skill performance.

Before discussing the implications of the study, it is important to note its limitations. In particular, while we attempted to maintain high levels of ecological validity in the design of this study, these findings may not generalize to a real-world setting in which decision-making requirements may be more complex than in this laboratory study. In addition, the findings from this study may only be applicable to participants who could be described as skilled recreational players. The pattern of attentional demands of a volleyball set for novice performers or elite volleyball players may be different from that reported here.

If the findings of this study generalize to a real-world setting, then they may have practical implications for coaching and instruction with this type of task. It is well established in the expert-novice literature that expert sport participants selectively attend to different cues than novice participants (Abernethy, 1990; Abernethy & Russell, 1987; Wright, Pleasants, & Gomez-Meza, 1990), and anticipatory cue usage training has been successfully implemented to improve sports performance (Singer et al., 1994). However, this applied research has focused primarily on attending to opponent-oriented cues, such as arm and racket location in tennis (Singer et al., 1994) or locations of opponents in the playing area (Wright et al, 1990). The findings presented in this study may have specific implications for anticipatory cue usage training in sports such as baseball, football, soccer, and volleyball, in which strategic decisions are often made while receiving a flying ball.

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Authors' Note

Please address all correspondence concerning this article to Benjamin Sibley, P. O. Box 870404, Department of Kinesiology, Tempe, AZ 85287-0404.