Attentional patterns of horseshoe pitchers at two levels of task difficulty

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Prezuhy, A.M., & Etnier, J.L. (2001). Attentional patterns of horseshoe pitchers at two levels of task difficulty. *Research Quarterly for Exercise and Sport, 72* (3), 293-298. https://doi.org/10.1080/02701367.2001.10608963

Abstract:

In a dual-task paradigm, two tasks are performed concomitantly, and their performance is assessed relative to the performance of each task individually. The decline in performance that occurs during dual performance has been attributed to the limits on a construct referred to as attention (Wickens, 1980). Nideffer (1976) described attention as "the ability to direct our senses and thought processes to particular objects, thoughts, and feelings" (p. 340). Three major groups of theories attempt to explain the mechanism behind this decline in performance. The structural theories suggest that a fixed limit to attentional capacity results in a "bottleneck" in human information processing (e.g., Broadbent, 1958; Keele, 1973; Kerr, 1973; Welford, 1952). The capacity theories suggest that the available attentional capacity (or pool) can be allocated in a graded quantity between separate tasks until the limit on this capacity has been reached (e.g., Kahneman, 1973; Knowles, 1963). The multiple resource theories suggest there are several "pools" of attentional resources, each of which has its own capacity and is designed for certain types of information processing (e.g., Allport, Antonis, & Reynolds, 1972; Navon & Gopher, 1979; Wickens, 1980).

Keywords: dual-task paradigm | reaction time probe technique

Article:

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In the motor learning literature, the attentional demands of a given task have typically been assessed using a particular type of dual-task paradigm called a reaction time (RT) probe technique (Schmidt, 1988; Wickens, 1984). This technique assumes that there is a fixed attentional capacity available to perform the primary task and that this capacity can be relatively assessed by examining performance on the secondary (RT) task. If performance on the primary task requires a large portion of the individual's limited attention pool, then only a small fraction of the attentional capacity remains to devote to secondary task performance. Thus, RT performance will suffer so that primary task performance can be maintained. Therefore, the amount of attention devoted toward the primary task will be inversely related to the level of performance on the secondary task.

For a concept as familiar as attention, it is surprising that only three studies have examined attentional demands for real-world sport tasks. Landers, Wang, and Courtet (1985) and Rose and Christina (1990) examined attention during shooting tasks, and Castiello and Umilta (1988) examined attention during gross motor sport tasks. Rose and Christina (1990) found that RT to the auditory probe increased in a near linear fashion, as the tone was presented at a time more temporally proximal to the time of the shot. Thus, they concluded that the demands on attentional capacity increased as the actual time of the shot approached. Castiello and Umilta (1988) examined the time course of attention in gross motor sport skills. Results with a volleyball service reception indicated that the level of attention directed toward the primary task increased as the time to reception shortened. Results with the reception of a tennis serve were similar with one important difference. In general, the RTs increased as the time to the reception of the serve neared; however, RT was slowest just as the ball landed in the near court and then actually was a little faster just as the ball was being received. This was the first time the peak of attention for a real-world sport task had been observed at a point in the movement other than as the task was being completed. With the running tasks, results indicated that attention to the primary task was greatest at the beginning and end of the race as opposed to any of the intermediate times measured. Castiello and Umilta's (1988) results are important in two ways. First, their results suggest that the time course of attention might be sport-specific. This reinforces the suggestion by Rose and Christina (1990) that each sport might need to be individually examined to understand the attentional demands of that sport. Second, in contrast to Rose and Christina (1990), Castiello and Umilta (1988) found that attentional demands across the time course of a task are not necessarily a monotonically increasing function.

The available studies provide a useful framework on which to build future research. That is, it is valuable to use the RT probe technique to examine the time course of attention, and it is beneficial to examine changes in the demands on attention as a function of task difficulty. The present study extends the literature by examining the time course of attentional demands for two difficulty levels of an as-yet-unstudied gross motor sport skill. Certain methodology used in the previous studies is improved on in the present study. In particular, performance on the primary task is examined to ensure that it is maintained during performance of the secondary task, the RT probe is administered at specified time points during the movement, and catch trials are included to minimize anticipation. Three hypotheses were developed based on the findings of previous research and anecdotal accounts from experienced horseshoe pitchers. The hypotheses are that: (a) RTs to secondary probes will be greater during experimental trials than during baseline trials, (b) RTs during the difficult task will be greater than RTs during the easy task, and (c) the pattern of RTs will not represent a monotonically increasing function.

Method

Participants

The participants were 40 adult horseshoe pitchers affiliated with local and national horseshoe-pitching organizations, who had at least 1 year of prior horseshoe pitching experience, and who normally used a 37-foot pitching distance, as specified in the rules of the National Horseshoe Pitchers Association of America (NHPA; 2000). All participants were asked to read and sign an informed consent. Participants were not selected based on age, gender, or handedness. With respect to age and gender, during "mixed open" competitions pitchers of any age and both genders can be placed in the same bracket to compete against each other (NHPA, 2000). Thus, it was considered appropriate to allow participation based on the same criteria to permit a valid generalization of conclusions to the real-world horseshoe-pitching population. Further, we did not hypothesize that there would be any differences in the attentional pattern as a function of age, gender, or handedness.

Participants were required to have a minimum of 1 year of horseshoe pitching experience for three reasons. First, the emphasis of the study was on the distribution of attention within a real-world gross motor sport skill. A logical extension of this premise was to use participants who were already familiar with the rules, techniques, and strategies of horseshoe pitching. Further, with experienced participants, it was expected that significant learning effects would not occur when executing the protocol. Therefore, it was assumed that each participant's level of performance on the primary task would remain consistent across blocks of trials. Finally, Landers et al. (1985) and Rose and Christina (1990) found that skill level and experience did not influence the distribution of attentional resources during task performance.

Materials

Primary task. The primary task for the present study was to pitch the horseshoes as closely as possible to the target stake. All participants pitched from the distance of 37 feet in both the easy and difficult task conditions. Each participant was permitted to use his or her own set of horseshoes (weighing less that 2lb 10 oz as per the NHPA rules) regardless of possible weight differences between sets, because weight differences are allowed in competitive situations and each individual was accustomed to pitching with his or her own equipment. Primary task performance was measured as the distance, to the nearest tenth of a centimeter, from the stake to the nearest point of the pitched horseshoe where it came to rest.

Task Difficulty. Two levels of task difficulty (easy, difficult) were created by manipulating the height of the target stake. This specific manipulation, as opposed to changing the throwing distance or increasing the weight of the horseshoe, was considered to be the most appropriate way to increase the level of task difficulty without corrupting either the mechanics or the integrity of the original task. For the easy version of the task, participants pitched horseshoes at a target stake that protruded 16 inches above the ground (NHPA rules). For the difficult version of the task, the target stake protruded 6 inches above the ground.

Condition Assignment. Participants were randomly assigned with respect to the order in which they executed the two experimental conditions. Participants either completed all trials of the difficult task before completing all trials of the easy task or vice-versa. This order was randomized and counterbalanced across the pool of participants.

Mistrials. A trial was considered a mistrial if a participant responded to the secondary probe after the thrown horseshoe landed, failed to respond to the secondary stimulus altogether, responded to the secondary stimulus before it was administered, or responded to the secondary stimulus on a catch trial. Data collected during a mistrial were dismissed (range of zero to five mistrials per participant), and the participant repeated the trial by pitching another horseshoe after the balance of trials for that experimental condition had been completed.

Secondary Task. The secondary task was to respond as quickly as possible to an auditory tone via the response device held in the pitcher's nonthrowing hand. Assessed by an electronic counter, secondary task performance was the amount of elapsed time, in milliseconds, between the presentation of the tone and the pitcher's response to the tone. The tone was presented randomly at one of three probe positions during execution of the pitching movement.

Response Device. It is common for competitive horseshoe pitchers to hold a hook-like device in their nonthrowing hand while pitching. Generally, this device is an 18-inch section of an old golf club grip and shaft bent at the bottom to form a hook. It is used to remove the horseshoes from the sand pit. In keeping with the experimental goal of ecological validity, this unique device was easily adapted for use as the response device for the secondary task by simply affixing an electronic switch to the top of the handle.

Auditory Tone Delivery. The auditory tone was presented through a speaker placed proximally to the pitcher. With horseshoe pitching, a certain range of mobility is required so that a participant can step, stride, and swing his or her arms as needed. This negated the possibility of using headphones to deliver the tone. Additionally, in the real-world task of horseshoe pitching, environmental noise from spectators and other background noise is the norm during performance, so the use of a speaker system helped to maintain ecological validity.

Probe Positions. The auditory tones were delivered at three probe positions, operationally defined across the pool of participants, as well as specifically matched to each pitcher's unique throwing style. Probe position 1 (PP1) was as soon as the hand of the throwing arm moved in any direction to execute a throw. Different pitching styles incorporate different initial hand movement directions, and some pitchers included "warm-up" swings or ritualistic prethrow movements. However, when executing the actual throw, the initial hand movement for all pitchers was consistently paired with a slight bend in the knee on the throwing arm side and a small step forward with the opposite leg. Thus, PP1 was considered to be the time when this combination of initiating movements occurred. Probe position 2 (PP2) was the point during the pitching motion when the participant's throwing hand reached its farthest extended position behind the body. Probe position 3 (PP3) was considered to be at the point just prior to the release of the horseshoe. This was identified as the time when the pitcher's arm came forward and the extended arm formed a 45° angle with the ground.

Catch Trials. The catch trials were used to eliminate any sense participants might develop for anticipating the secondary tone. That is, if the secondary stimulus was not presented at PP1 or PP2, a participant might have anticipated that it would be presented at PP3. The result in such a case might have been an erroneously fast RT at PP3. However, with the knowledge that a probe might not be presented at all, the anticipation effects were eliminated. Additionally, primary task performance on the catch trials was compared to baseline performance to ensure that the mere inclusion of the secondary task did not impact primary task performance.

Procedure

Prior to beginning the experiment, participants were allowed two to three warm-up throws. Participants then performed 10 trials of the secondary task as a baseline measure of RT. RT measures to the secondary probe were collected while the participant was in a neutral standing position on the pitching platform facing the target stake. During these trials, the participant held the response device in the nonthrowing hand and one horseshoe in the throwing hand. Baseline RTs were collected for later comparison to the RTs collected during the easy and difficult experimental trials.

Baseline measures were also collected for performance on the primary task at each level of task difficulty. Ten baseline trials were conducted at each level of task difficulty just prior to performing the experimental trials at that same level of task difficulty. Participants made baseline throws while holding the response device but without the threat of a secondary probe. The collection and analysis of baseline performance measures served two purposes. As a manipulation check, analyses were performed to ensure that mean performance on the baseline trials was not significantly different from mean performance on the respective experimental trials for either level of task difficulty. Additionally, participants were carefully observed while performing their baseline trials so that it was known precisely when the three operationally defined probe positions occurred during each participant's throwing motion (e.g., Rose &Christina, 1990).

At each level of task difficulty, each participant completed 40 experimental trials. Participants received a short rest period between experimental conditions so that the experimenter could change the height of the target stakes. Participants were not permitted to take additional practice throws during the rest period. Within each level of task difficulty, the auditory stimulus was randomly presented 10 times at each probe position. The remaining 10 trials in each condition were randomly presented catch trials.

Each participant was videotaped during his or her full range of trials. The videotape of five randomly selected participants was later examined with respect to the reliability of the experimental probe presentation. After completion of the study, two independent raters assessed the accuracy of probe administration relative to the operationally defined probe positions. These raters agreed with the timing of the probe administration on 92% of the trials.

Results

Statistical Analyses

Means and standard deviations are presented in Table 1.To ensure that task difficulty was successfully manipulated, two analyses were conducted. Primary task performance during baseline performance trials was examined using a one-way repeated measures (RM) analysis of variance (ANOVA), with level of difficulty as the independent variable. Primary task performance during experimental trials was also examined using a two-way RM ANOVA with level of difficulty and probe position (PP1, PP2, PP3, catch) as the within-subjects independent variables.

Table 1. Means and standard deviations for primary task performance (distance from the stake) and secondary task performance (reaction time)

	Baseline		**PP1**		**PP2**		**PP3**		**No probe (catch trials)**		**Collapsed across PP1-PP3**	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Primary performance on easy task (cm)	21.19	8.93	22.19	10.53	21.34	11.58	22.16	11.04	20.98	10.10	21.90	10.30
Primary performance on difficult task (cm)	24.61	11.03	26.50	10.55	25.80	14.23	24.41	9.90	25.43	12.61	25.57	10.81
Secondary performance on easy trials (ms)			363.18	62.10	336.15	42.00	350.38	39.12			349.90	40.99
Secondary performance on difficult trials (mc)			378.12	50.53	342.22	44.51	362.03	47.27			360.79	32.71
Secondary performance across levels of difficulty (ms)			370.65	53.56	339.19	38.28	356.21	34.47				

Note. PP1 = probe position 1; PP2 = probe position 2; PP3 = probe position 3; *M* = mean; *SD* = standard deviation.

To ensure that primary task performance was maintained during the experimental trials, three analyses were conducted. For each level of task difficulty, primary task performance was examined using a one-way RMANOVA with probe position (PP1, PP2, PP3, catch) as the independent variable. A 2 x 2 (Level of Difficulty x Experimental Manipulation) RM ANOVA with repeated measures on both factors was used to compare primary task performance at baseline with primary task performance during experimental catch trials.

To examine the time course of attentional demands relative to the level of difficulty of the task, RT was examined using a Level of Difficulty (easy, difficult) x Probe Position (PP1, PP2, PP3) RM ANOVA with repeated measures on both factors. When significant main effects were found, *t* tests were used to elucidate the nature of these findings and a Bonferroni adjustment was made to control for experiment-wise error.

Level of Difficulty Manipulation Checks

Baseline Performance Trials. There was a significant main effect for level of difficulty on baseline performance, $F(1, 39) = 15.49$, $p < .05$, such that performance (distance in cm from the stake) for the difficult task was significantly worse *(ES* = 0.34) than performance for the easy task.

Experimental Trials. There was a significant main effect for level of difficulty, $F(1, 39) = 28.72$, $p < .05$, on performance. Primary task performance for the experimental trials on the difficult task, $M = 25.54$, $SD = 11.03$, was significantly worse ($ES = 0.21$) than for the easy task, $M = 21.67$, $SD = 9.92$. Neither the main effect for probe position, $F(3, 117) = 0.72$, nor the Level of Difficulty x Probe Position interaction, $F(3, 117) = 1.01$, was significant, $p > .05$.

Maintenance of Primary Task Performance

Easy Task. The main effect for probe position on performance of the easy task was not significant, $F(3, 117) = 0.58$, $p > .05$. Thus, primary task performance was maintained across the different probe positions and the catch trials.

Difficult Task. The main effect for probe position on performing the difficult task was not significant, $F(3, 117) = 1.09$, $p > .05$. Thus, primary task performance was maintained across the different probe positions and the catch trials.

Baseline Versus Experimental Catch Trials. Results revealed a significant main effect for level of difficulty, $F(1, 39) = 21.19$, $p > .05$, on primary task performance. Performance on catch trials was significantly worse ($ES = 0.39$) in the difficult condition as compared to performance in the easy condition. Neither the main effect for experimental manipulation, $F(1, 39) = 0.29$, $p > .05$, nor the interaction of Level of Difficulty x Experimental Manipulation, $F(1, 39) = 1.09$, $p > .05$, was significant. Thus, primary task performance was not influenced by experimental condition.

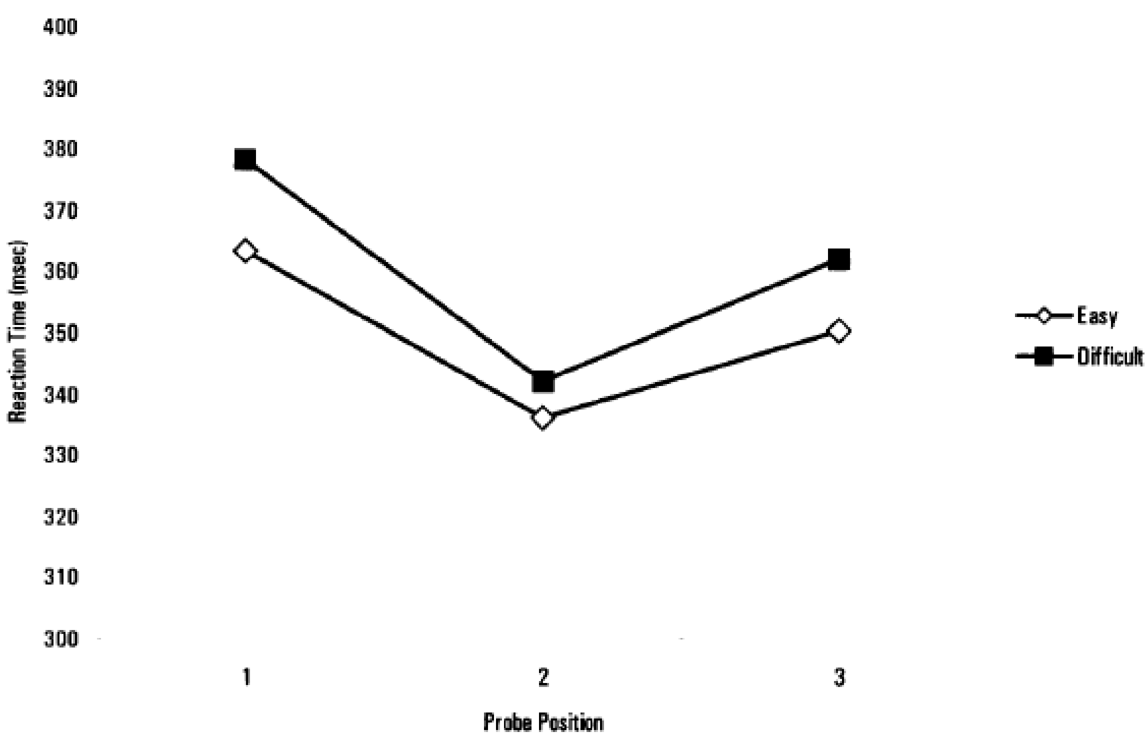

Figure 1. Mean reaction time as a function of task difficulty and probe position.

Time Course of Attention

Results indicated a significant main effect for level of difficulty, $F(1, 39) = 6.42$, $p < .05$. Across probe positions, RT was significantly faster, ES= 0.16, on the easy trials than on the difficult trials (see Figure 1). There was also a significant main effect for probe position, $F(2, 78) = 10.17$, $p < .05$. Across levels of difficulty, RT at PP1 was significantly slower, $t(39) = 4.85$, $P < .05$, than RT at PP2. RT at PP3 was also significantly slower, $t(39) = 2.65$, p« .02, than RT at PP2. RT at PP1 was not significantly different, $t(39) = 1.82$, $p > .05$, from RT at PP3. The Level of Difficulty x Probe Position interaction was not significant, $F(2, 78) = 0.46$, $p > .05$.

Discussion

When using the RT probe technique, it is critical to first establish that performance on the primary task is maintained when the secondary task is present. If primary task performance suffers when the secondary task is introduced, then it is inappropriate to conclude that secondary task performance is indicative of the amount of attentional resources devoted to the primary task. This is because an equally reasonable conclusion would be that, at some point, the individual reprioritized the primary task and the secondary task. Thus, any conclusions drawn with respect to the attentional time course of the primary task would be confounded. Importantly, the results of this study indicated that participants were able to maintain performance on the primary task (throwing the horseshoe) when the secondary task (responding to the auditory stimulus) was introduced. Given the satisfaction of this requirement, the logic underlying the RT probe technique suggests that performance on the RT task is indicative of the attentional demands of the primary task. That is, a limited attentional capacity is assumed, and RT is used to make inferences about the demands being placed on attentional capacity by the primary task. In this study, the RT probe technique was successfully used to measure attentional capacity relative to two independent variables.

First, primary task difficulty was manipulated so the RTs to the secondary task could be used to make inferences about the influence of task difficulty on the attentional demands of the primary task. Results indicated that the manipulation of task difficulty was successful, because participants were less accurate when throwing at the shorter stake (the difficult task) than when throwing at the taller stake (the easy task). Results also indicated that RTs (at all probe positions) were slower during the difficult task than during the easy task. These findings support those of past research (Castiello & Umilta, 1988; Landers et al., 1985) and indicate that a greater portion of the individual's limited attentional resources were devoted to the primary task in the difficult condition as compared to the easy condition.

Second, auditory probes were administered at different time points across the execution of the primary task. Results indicated that the level of attention devoted to the primary task of pitching horseshoes changed as a function of time. At both levels of task difficulty, RTs were faster at PP2 and slower at PP1 and PP3. This suggests that regardless of task difficulty participants devoted more of their attentional resources toward the primary task at the initiation of the pitch (PP1) and just prior to release of the horseshoe (PP3) than they did at full extension on the backswing (PP2).

At first glance, a review of the past research seems to indicate that observed attentional patterns will be linear for fine motor sport skills and nonlinear for gross motor sport skills. In fact, the results of this study support this conclusion, because a nonlinear pattern of attention was found for the gross motor sport skill of horseshoe pitching. However, the assumption of one large division between fine motor and gross motor sport skills with respect to patterns of attentional demands might be too general. A more careful examination of the literature indicates that the shooting studies exhibit an attentional pattern different from tennis, volleyball, or running, each of which exhibited a unique attentional pattern. These results then might suggest that each sport has its own specific pattern of attentional demands. However, this explanation might be too specific to be realistic. That is, based on such limited research it is hard to assume that every sport-related skill will exhibit a pattern of attentional demands different from every other sport-related task. Therefore, if attempting to divide the patterns of attentional demands of sport skills into fine motor and gross motor tasks is too general and if labeling patterns of attentional demands as being unique for each sport is too specific, then the answer might lie somewhere in the middle. That is, it might be more appropriate to conclude that particular classes of skills can be determined based on the required interactions with external stimuli, and these classes of skills might then exhibit general patterns of attentional demands. Skills such as horseshoe pitching, bowling, and throwing might be classified as "projection" tasks. Similarly, hitting a pitched ball or receiving a tennis serve or volleyball serve might be classified as "reception" tasks. Tasks such as driving a golf ball and kicking a field goal might be classified as "striking" tasks. The basis for an "aiming" classification of tasks might already have been formed through the shooting research by Landers et al. (1985) and Rose and Christina (1990).

The results of the present study illustrate a unique attentional pattern for the act of horseshoe pitching, and it is suggested that this pattern might generalize to other tasks, which could be classified as projection tasks. Additionally, it is suggested that other tasks, which are similar in the required interactions with external stimuli, might share common patterns of attention. However, experimental research is needed to test these hypotheses. Additionally, further elucidation of attentional patterns within particular types of tasks might be beneficial, because this information might be used to enhance teaching strategies and improve performance.

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