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The purpose of this research was to use the dual-task paradigm to examine the effect of a secondary reaction time task on free throw performance and to determine the point of peak attentional demand during the free throw process. Thirty subjects, ranging in age from 18 to 62 years ($M = 23.9 \pm 8.3$), with at least two years basketball experience at the high school level comprised the sample. After baseline measures, each subject completed 40 free throw trials. During the free throw, the participant was instructed to respond verbally to a sound stimulus to determine reaction time (RT). The sound stimulus was administered at one of 4 probe position (PP) conditions or was not administered (catch trial condition).

Repeated measures ANOVA showed no significant difference in performance as a function of condition (probe position), suggesting that participants were able to keep the free throw as the primary task, assigning it the most attentional weight. Given these results, any increases or decreases in reaction time performance across probe positions could be attributed to an increase or decrease in attentional demand, respectively. A second repeated measures analysis showed a significant difference in reaction time as a function of condition. Tests of simple contrasts showed that reaction time at probe position (PP)1 and PP2 were significantly higher than baseline reaction time. These results suggest that the pre-shot routine (PP1) requires the greatest attentional demand, followed by the first upward motion of the ball.

ACCURACY OF FREE THROW SHOOTING DURING DUAL-TASK PERFORMANCE: IMPLICATIONS OF ATTENTIONAL DISRUPTION ON PERFORMANCE

by

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APPROVAL PAGE

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CHAPTER I

INTRODUCTION

We often encounter evidence to our limits in attention. Daily we do our best to perform multiple tasks at the same time. We make business calls while driving from work and we balance our checkbook while we cook dinner. However, we find that no matter how programmed we are to perform a certain task, some kind of interference will affect the performance of one, if not both, actions. One example is the combination of driving while conversing. The conversation is interrupted when the demands of the driving activity become critical. Even the highly automated act of walking requires some attentional capacity. If you are casually walking with a friend and ask him to perform a difficult multiplication task he is likely to stop in his tracks.

One of the classic dilemmas of psychology concerns the division of attention among multiple streams of incoming information. William James (1890) defined attention as "The taking possession of mind in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. It implies withdrawal from some things in order to deal effectively with others…" (pg. 403-404). The definition itself supports the idea that attention is a constant battle of attending to the appropriate information at the appropriate times. James also implies that the ability to withdraw attention from certain stimuli in order to attend to others is not passive, but requires intention and conscious effort. Pashler and Johnston (1998) offer two criteria that a performance limitation must satisfy to be considered attentional. First, the limitation must not be a direct consequence of the structure of the human body. For example, our inability to drink a cup of coffee and type on a keyboard at the same time is not attentional. Second, an inability to perform two tasks at the same time to a given criterion of performance is attentional only if a person could voluntarily perform either task alone to that criterion under the same conditions, thus demonstrating a type of capacity interference. Therefore, our inability to comprehend two spoken messages at the same time does qualify as attentional. Pashler and Johnston (1998) state that true attentional limits are caused by limitations on those parts of mental machinery or process that are normally subject to voluntary control or direction.

According to Kahneman (1973), these observations lead to two predictions: (1) interference occurs even when the two activities do not share any mechanisms and (2) the extent of interference will depend in part on the attentional load which each of the activities imposes. Therefore, the performance on any task performed concurrently with another task is likely to be interrupted by a kind of structural or capacity interference, and the extent to which this interference impacts performance is determined by the amount of attention the task requires. There are two types of attention models that emphasize the limitations of the mental system; the Structural "Bottleneck" Model and the Capacity Model. While both types predict that concurrent activities are likely to be mutually interfering, they ascribe the interference to different causes. In the structural, bottleneck model, interference occurs when the same mechanism is required to carry out two operations at the same time (Kahneman, 1973; Pashler & Johnston, 1998). In a capacity model, interference occurs when the demands of two activities exceed available capacity (Kahneman, 1973). While the exact cause ascribed to interference is not certain and both theories are supported by vast amounts of research, we do know that interference during the simultaneous execution of multiple tasks does occur.

Although this subject is popular in cognitive psychology literature, it is not so prominent within the study of sport performance. Numerous sport skills require an athlete to process multiple forms of information at once. This demand places the athlete in a dual-task situation, where he or she must not only divide attention, but decide what information is relevant to performance, what is irrelevant, and determine the attentional weight to be assigned to each task based upon its importance to performance. By subjecting an individual to a controlled dual-task situation, we are able to quantify the attentional demands of the primary task by measuring performance on the secondary task. Knowledge of the attentional demands of a sport skill can help athletes who are susceptible to distractions and have trouble controlling attentional processes by identifying the points of a particular task when undivided attention is essential. Those who study human performance can take information from existing psychology literature and use this to make sense of behavior in sport. The application of attention research from psychology to sport is important and valuable to the influence of sport psychology on athletic success.

The role of higher attentional processes in sport is important to determine how the athlete becomes exceptionally accurate in the performance of certain skills (Vickers, 1996). For example, is peak accuracy attained only when focusing attention on one particular target, or can we maintain accuracy while directing attention to multiple performance cues? How can a volleyball player find “a hole” in the opponents’ court while still focusing in on and trying to hit a moving target? Does accuracy of performance decline as attention is divided? Can we control the amount of attention we allocate to a particular task? Research examining the attentional tendencies of individuals has been used to generate an understanding of how one manages to process multiple forms of information simultaneously. Specifically, Sibley and Etnier (2004) studied the distribution of attentional resources during a decision making and reaction time task related to the volleyball overhead set. Their results for identifying time of peak attention of the volleyball overhead set has important implications for volleyball players and coaches who want to understand how their attention is divided between tasks and the effect this has on performance. For example, Sibley and Etnier found that while attentional resources are well-shared between tasks during the middle portion of ball flight, there is an increase in attentional demand during the initial and last portion of the ball’s flight. This increase in attentional demand is likely due to the increase in attentional resources needed to gather information on ball speed and direction, as well as to make small proprioceptive adjustments needed to make contact with the ball. With this type of information, we can instruct athletes to focus on and selectively attend to the most important cues during performance of a particular skill, ultimately improving performance. In addition, information on how one distributes attention during sport tasks can be helpful in understanding the effects of distractions and when these distractions are most devastating to performance.

The difference in free throw accuracy among individuals playing at elite levels of basketball is dramatic. In the 2007 season, only nine individuals competing at the NCAA Division One level achieved a free throw percentage above ninety percent (http://cbs.sportsline.com/). Greg Oden, freshman standout and the number one draft pick in the 2007 NBA draft, shot only 63.2% during the 2006-2007 season (http://ohiostatebuckeyes.com/). To put this in perspective, Oden shot 61.6% from the field; with one, two, and sometimes three defenders in his way. How can such a skilled athlete shoot so poorly? Does the free throw require the use of skills beyond what can be controlled by physical ability? Although the free throw poses challenging experimental problems, these are offset by benefits derived from studying the human in challenging conditions.

Purpose and Hypotheses

The broad purpose of my study is to add to the existing knowledge on attention and performance in sport by examining basketball free throw shooting within the dual task paradigm. Specifically, I hope to 1) determine the effect of a secondary auditory-tone task on the primary free throw task performance. In addition, by applying the Capacity Theory and using the well-established reaction time probe technique, I hope to 2) determine the time course of attention of the basketball free throw and assess the allocation of attention to the performance of multiple tasks. The results have strong potential to provide coaches and athletes with information that can be used to improve free throw performance.

In general, dual-task processing negatively influences the performance of a motor task when the secondary task is introduced; these negative effects being most pronounced at the point of highest attentional demands. However, when each task is assigned a weight (first priority, second priority), it is expected that performance on the primary task is maintained when the secondary task is present. This is because a steady performance on the primary task throughout the experiment indicates that all attentional resources were devoted to the primary task, and performance on the secondary task signifies any attentional reserves that are still available (Prezuhy & Etnier, 2001). Therefore, a primary task that demands greater attentional resources leaves less available for other tasks, causing a decrease in secondary task performance. In this particular study, as long as each subject keeps performance of the free throw task as primary importance, we would not expect to see a decrease in free throw performance when the auditory tone is introduced. However, we would expect that because verbal response to the tone is of secondary priority, those points of the free throw process that require the greatest attentional demand will take up more central processing space, causing decreased performance (slower reaction time) on the auditory reaction time task compared to baseline reaction time performance. In particular, I expect to see the slowest reaction times during probe position 2 (pre-shot) and 3 (shot), when the shooter's attention is directed to kinesthetic movement. I expect that attention to the position of the limbs during these phases is critical to carry out precise muscle coordination and maintain proper technique in order to make a shot.

CHAPTER II

REVIEW OF LITERATURE

The distribution of attentional resources is of primary interest in those studies examining how athletes allocate attention to multiple incoming stimuli during sport performance. There are many theories that have been proposed to explain why decrements are observed in performance requiring the processing of multiple information or stimuli. Structural models attribute limits in attention to mechanisms in the brain that are only capable of carrying out one operation at a time. Both the attentional blink and psychological refractory period seek to explain interference found in dual-task studies due to this type of limitation. Equally, the capacity theory attributes limits in attention to the competition for a limited amount of resources. This is based upon the mind's flexibility and ability to switch attention between tasks from moment to moment. This concept of limited attentional capacity has guided research on attention in real-world sports because of the frequency with which athletes are faced with a situation in which they must process multiple stimuli and types of information simultaneously. These situations are common in sport and can strain attention, leading to overload.

In light of this information, the dual-task paradigm was developed, and studies which tested individual's performance during a dual-task situation yielded interesting results. The dual-task paradigm was soon used in the study of sport behavior and performance. From baseball to horse-shoe pitching, researchers found that the time course of attention could actually be determined. Using a dual-task set-up and a reaction time probe technique, it was found that levels of attention are not consistent across the entire performance, but that attentional demands vary throughout a task. Because we believe that focusing strategies such as imagery or the use of cues can be utilized by athletes to enhance performance, identifying the exact pattern of attentional demand for a particular task can facilitate the teaching and learning of not only what to direct attention to, but also the most appropriate times to focus attention. Although research focusing on attention is extensive, researchers are not in complete agreement on explanations of the attentional phenomena that studies have revealed. Overall, however, the literature does agree that attentional resources are indeed limited and the processing of multiple forms of information does create a type of interference that limits task performance; performance that is critical to individual and team athletic success.

One of the earliest studies on the division of attention took place in 1887, when Paulhan recited one poem aloud while repeating a different one mentally (James, 1890). He found that two operations of the same sort render the process more uncertain and difficult. Paulhan continued his studies by comparing the time occupied by the same two operations done simultaneously or in succession. In these studies he found that there was often a considerable time gain from doing them simultaneously. He found that while a reciting task alone took 22 seconds and a writing task alone took 31 seconds, it took 40 seconds to perform both tasks simultaneously. If attention could be divided among multiple tasks without cost, we would expect the total time to perform both tasks simultaneously to equal the time it takes to perform the longest single task; in this case, 31 seconds. In addition to these findings, it was observed that if two stimuli are perceived simultaneously, we observe that the responses they elicit are often made in succession rather than simultaneously (Kahneman, 1973). Therefore, according to these observations, cognitive psychologists found very early that the ability to attend to a stimulus is compromised when one task interferes a good deal with the perception of another. Two of the better-known forms of this dual-task interference are the attentional blink effect and the psychological refractory period effect.

Attentional Blink Effect

One of the most striking and compelling examples of dual-task interference is the attentional blink (AB). In this paradigm, subjects view a stream of visual items, each presented in the same location on a computer monitor (Chun & Potter, 2001). This presentation technique is known as rapid serial visual presentation (RSVP). The subjects must report two targets within the RSVP stream. The stimulus onset asynchronies (SOA) allow researchers to map a precise time course of interference. The SOA represents the time between the onset of one stimulus and the onset of a second stimulus. While SOA between stimuli can be positive (onset of the second stimulus follows the onset of the first) or negative (onset of the second stimulus precedes onset of the first), or equal (simultaneous onset of both first and second stimulus), attention and dual task studies use a positive or equal SOA (Higgins, 2004). When human observers are asked to perform two simple tasks in rapid succession, one often observes a noticeable cost. That cost grows larger as the time interval between the two tasks is made shorter (Van Selst & Jolicoeur, 1997). Typically, subjects can accurately report the first target, but tend to either exhibit a dramatic impairment or completely miss the second target when it appears within 300-400 ms of the first (Ruthruff & Pashler, 2001). This deficit is called the “attentional blink”.

The attentional blink demonstrates capacity limitations for consolidating visual information into working memory and awareness (Chun & Potter, 2001). However, what we don’t know is why performance in detecting a secondary task is affected. While some propose that AB occurs because of a competition for retrieval between the two targets, others state that all targets are identified but lost before entering a later stage of processing. (Chun & Potter, 2001). The possibility that the cost on the second task performance reflects a limitation in human information processing continues to sustain interest in understanding dual-task interference (Van Selst & Jolicoeur, 1997).

Psychological Refractory Period

In one of the earliest attempts to explain performance in a dual-task situation, Welford (1952) reviewed the limited research of Hick and Vince regarding reaction time rapid response sequences and formed theory on the psychological refractory period. The notion of a psychological refractory period has arisen from studies of reaction times to serial stimuli (Welford, 1952). Most observers can consistently recognize a single target embedded within a RSVP display, even when the target is presented for only a tenth of a second (Ruthruff & Pashler, 2001). After detecting one target, however, observers frequently have difficulty detecting targets that appear within the next several hundred milliseconds. (Broadbent and Broadbent, 1987). This type of dual-task interference is attributed to the psychological refractory period (PRP) effect, which occurs when subjects are asked to make speeded responses to two different stimuli.

When testing PRP, subjects are presented with two tasks, each requiring a separate speeded response. The key independent variable is the time between the stimulus onsets, or SOA. Although the response time to task 1 usually does not depend much on the SOA, the response time to task 2 can be elevated by 300 ms or more at short SOAs (Ruthruff & Pashler, 2001). Therefore, while task 1 is being processed, task 2 must wait, hence, a refractory period. The explanations given for this phenomenon are varied. Luck and Vogel (2001) found that the PRP primarily reflects an impairment in a response-related process, suggesting that the activation of working memory and the selection of a response may require access to the same system. Therefore, subjects can not select a tone response while they are busy retrieving information from memory. Similarly, according to this theory, athletes can not simultaneously make two responses if each task competes for the same response system's resources.

While the AB effect and PRP are similar in that they attribute a decrement in dual task performance to an interference caused by structural limitations, they differ in several respects. Regarding experimental design, the PRP requires a fairly simple perceptual task. Subjects however, are pressured to produce their responses very quickly (Ruthruff & Pashler, 2001). In contrast, the AB design involves a more difficult perceptual task, but without any pressure to select a particular response quickly. In addition, the location of interference between the AB and PRP is ascribed to different places. Interference in the AB design appears to surface in perceptual processing while interference in the PRP design is believed to occur in response selection and other decision-making processes (Ruthruff & Pashler, 2001). Although AB and PRP are traditionally studied independently from another, they both appear to be a manifestation of a central bottleneck limitation, which arises in the dual-task paradigm when the two tasks compete for the control of the response-selection stage (Welford, 1968).

Bottleneck Theory

Welford (1968) proposed this single-channel theory to explain why interference arises during the simultaneous performance of two tasks. Many suggest the image of a bottleneck to explain a stage of internal processing which can only operate on one stimulus or one response at a time (Kahneman, 1973). According to this "central bottleneck" theory, dual-task costs occur because central processing for one of the tasks must be delayed while the central mechanism is occupied by another task. This refers to the idea that certain critical mental operations are carried out sequentially, and a bottleneck arises whenever two tasks require a critical mental operation at the same point in time (Pashler & Johnston, 1998). The most obvious explanation for the existence of bottlenecks would be that the mind/brain contains only a single device or mechanism capable of carrying out operations. Thus, dual-task costs should be observed whenever two tasks are temporally aligned so as to simultaneously require central processing.

The filter theory, proposed by Broadbent (1957), assumes a bottleneck at or just prior to the stage of perceptual analysis, so that only one stimulus at a time can be perceived. On the other hand, Deutsch and Deutsch (1963) state that the bottleneck is located at or just prior to the stage of response selection, stating that sequential processing prevents the initiation of more than one response at a time. Ruthruff and Pashler (2001) conducted several tests of the unified central bottleneck (UCB) model, and found that there is some constraint that prevents the simultaneous occurrence of any two operations, therefore supporting the UCB model. A striking failure of parallel processing was also reported by Colavita (1971). His subjects were instructed to press one key to a light flash and another key to a tone. Although the subjects expected a single event on each trial, both were presented on the same trial at some points. On 49 of 50 of those dual-task trials, subjects pressed the "light" key alone. More interesting, on 17 of those 49 trials the subjects were unaware that the tone had even been presented. In this case, Colavita found that a visual stimulus is clearly dominant over a concurrent auditory stimulus, capturing both awareness and response.

The selection of a response is often highly demanding of attention and effort. As a result, activities that demand the same response selection are considered content-dependent interference, and will tend to interfere with other activities. Pashler and Johnston (1998) refer to this as "crosstalk," or impairment in performance that hinges directly on the specific content of the information being processed. During content-dependent interference, any response to a particular stimulus that will require a specific set of central operations that is similar to the response to a secondary task will result in dual-task interference (Hazeltine, Ruthruff, & Remington, 2006; Pashler & Johnston, 1998). For example, Greenwald (1972) studied whether two independent decision tasks can be performed simultaneously with perfect efficiency. He hypothesized that this should be possible only if the two tasks do not share in the use of any limited-capacity information-processing system. However, Greenwald found that a conflict in the response systems between two tasks tended to increase reaction times. Therefore, utilizing tasks that require different central codes such as a visual-manual and auditory-vocal operation minimizes the opportunity for content-dependent interference between tasks, suggesting that performance costs can instead be attributed to interference due to capacity limitations. Provided that there is no response overlap between the stimuli and/or responses for the two tasks, dual-task costs should be determined by a limit in capacity, and not by interference caused by the specific relationships between the two tasks as described by AB, PRP, or UCB (Hazeltin, Ruthruff, & Remington, 2006). Hence, if participants perform two tasks that do not compete for the same response system resource, such as the auditory–vocal task and visual–manual task as this study proposes, current theories tell us that performance costs should arise only from competition for limited central resources.

Capacity Theory

Capacity Theory assumes that limited, available attentional resources can be allocated with considerable freedom among concurrent activities (Kahneman, 1973). However, different mental activities impose different demands on the limited capacity. An easy task demands little effort, and a difficult task demands much. In support of capacity theory, Posner and Rossman (1965) asked subjects to retain three letters for a brief interval during which they engaged in mental tasks of varied complexity. The amount of retention decreased regularly with increasing difficulty of the secondary task, demonstrating how an increase in attention to one task leaves less attention available for a second task. Therefore, capacity theory states that when the supply of attention does not meet the demands, performance falters, or fails entirely.

Kahneman (1973) put forward a theory that describes attention as a limited resource that can be flexibly allocated from moment to moment. When tasks are more difficult, more attention is needed. Task difficulty is determined by the amount of interference on a concurrent task (Styles, 2006). When two tasks are combined, resources must be allocated between both tasks. Depending on the priorities we set, more or fewer resources can be allocated to one or other of the tasks. Posner and Boies (1971) conducted an experiment that asked subjects to do two things at once. One task involved letter matching, in which a warning signal was followed by a letter. After half a second, another letter was presented and the subject had to judge whether or not the letters were the same. However, at the same time, subjects were also monitoring for the presentation of an auditory tone. Posner and Boies found that the allocation of attention could be detected by measuring reaction time to the auditory tones at different times during the visual task. If the tone was presented at the same time as any of the letters, response was slower, but not as slow as when the tone was presented during the interval between the two letter presentations. This experiment was taken as evidence for a general limit on attentional processing. During the "easy" part of the visual task, attention is free to support the tone detection task; but in the "difficult" part of the visual task, which demands attention, there is less attention available for tone detection or response (Styles, 2006). Through experiments based upon this dual-task paradigm, the attentional demands of a particular task can be derived by asking subjects to perform two tasks concurrently. One of the most useful methods for studying divided attention and limits on attentional capacity is the dual-task paradigm (Karatekin, Courperus, & Marcus, 2004).

Dual-Task Paradigm

The dual-task paradigm was developed to assess the amount of attention devoted to a particular task at any given time (James, 1890). The basic assumption is that different tasks demand varying degrees of processing and that the simultaneous performance of tasks can cause overload on the limited capacity system (Kahneman, 1973). Our minds work similar to the memory of today's computer. RAM (Random Access Memory) is a type of data storage used in computers that allows information to be accessed when needed. While the memory in every computer is limited in capacity, the ability to access information and data at any given moment is also determined by the number of operations being performed at one time. For example, similar to human information processing, the speed at which the computer is able to retrieve then processes information slows when more programs are being used at one time.

When the limited capacity system is exceeded, dual-task interference is produced and performance begins to deteriorate compared to single-task performance (Bourke, 1997). Therefore, the dual-task paradigm was developed and is commonly used to test capacity limits. In a dual-task setup, participants are asked to complete a primary task alone, and then concurrently with a secondary task. Performance on the secondary task is assessed and used to derive the attentional demand of the primary task. A primary task which requires greater attentional demand will take up more central processing space, causing decreased performance on the secondary task (Sibley & Etnier, 2004). This information is based on a more broad, general resource theory.

In general resource theory, performance on a task is related to the level of resource allocated to the task (Bourke, 1997). Kahneman (1973), one of the foremost researchers to emphasize the active nature of attentional control, proposed that the recruitment of resources is equated with exertion of mental effort and with how hard we pay attention. His theory relates a level of physiological arousal to an amount of resources or capacity. The more difficult a task, the more resources required, and the greater the arousal.

The dual-task design permits the comparison of different tasks in common units. The quality of performance on a secondary task provides a measure of the load imposed by the primary task (Kahneman, 1973). Beyond a minimum level of resource allocation, performance improves as the level of mental effort allocated to the task is increased (Bourke, 1997). However, if the level of attention required to perform two tasks optimally exceeds that available, dual-task interference will be observed. The level of interference will depend on the extent to which demand for attention exceeds the supply available (Bourke, 1997).

Allocation of attention to a task increases with its weight, or importance in a particular situation, but decreases with the weight of the other, competing task (Bourke & Nimmo-Smith, 1996). For example, when we are driving and conversing we assign more weight (importance) to the task of driving. Therefore we would say this was our primary task. However, because attentional resources are believed to be limited, as the demands of the conversation (secondary task) increase, it competes for attention. Unless we are able to allocate all of the necessary attentional resources to the primary task, we may find that our ability to drive safely becomes threatened.

The dual-task design can provide us with significant information on the attentional weight required to perform a specific task. In a dual-task experiment, each task is assigned a weight, indicating how strongly it competes for limited attentional resources (Bourke & Nimmo-Smith, 1996). The greater the weight of a primary task, the greater its interference with all secondary tasks being performed concurrently. If we find a greater interference (as indicated by decreased performance on secondary task) using primary task A as compared to primary task B, we can conclude that task A requires a greater attentional demand than task B. Similarly, if we find an increase in reaction time at the beginning of a task as compared to the end of a task, we can conclude that the beginning of the task requires more attentional demand. Therefore, the purpose of a dual-task setup is to evaluate the attentional demand of a primary task, as well as assess the amount of interference occurring by measuring decreases in performance on the secondary task.

Applying Dual-Task to Sport. Research using a dual-task paradigm in real-world sport settings is useful for both determining time course of attention for a particular task and the impact of multiple tasks on attentional demands. Sibley and Etnier (2004) used a dual-task paradigm to examine (1) the pattern of attention demands in the volleyball set, and (2) the impact of a chosen cognitive task (decision making) on the attentional demands and task performance. The study included both a ball-tracking component and a projection-striking component in order to assess time-course of attention, and a decision making task to determine whether or not a choice about where to set the volleyball increases the attentional demands of the task. In addition to using simple set (predetermined direction) and choice set (direction determined by ball color) conditions, attention demands were measured at four different time points (probe positions) from the time the ball was tossed to the participant to the time of contact with the ball. Probe positions 1 through 4 were defined as (1) as the ball is being tossed, (2) just prior to the peak of the toss, (3) just after the peak of the toss, and (4) just prior to the ball touching the subject's hands. Significant main effects were found for task difficulty and probe position. Results for simple sets showed a significantly greater reaction time (RT) at probe position (PP)1 and PP4, and for choice sets a significantly greater RT at PP1. This indicates that the greatest attentional demand was during the initial portion of the ball's flight. These results are consistent with previous studies that had tracked eye-movement and found that performers do not need to track the entire ball flight but rather track the initial flight of the ball, and then "shoot ahead" to the final portion of flight (Land & McLeod, 2000). Lastly, the addition of the decision-making requirements was found to negatively affect setting accuracy by resulting in a significant decrease in setting performance when the participants were forced to choose their set direction. These results verified that having to make several decisions simultaneously required increased information processing and attentional demand, giving plausibility to the general resource theory and providing further evidence that the observable decrease of performance was caused by the overloading of a limited capacity system.

One of the main advantages of the dual-task approach is that it is possible to determine where participants direct attention during performance (Castaneda & Gray, 2007). In order to make different performance predictions based on this methodology, Castaneda and Gray (2007) looked at performance during four conditions; Skill/Internal focus, Skill/External focus, Environmental/External focus, and Environmental/Irrelevant focus. Skill-focused attention is defined as attention to any aspect of the motor action such as the position of the limbs or movement of a bat. Environmentally-focused attention is attention to anything in the environment not directly involved in skill execution, such as the position of the opponent or sounds from the crowd. In the Environmental/Irrelevant condition, Castaneda and Gray directed attention away from skill execution by asking participants to judge whether the frequency of a tone was high or low. They found that for both highly- and less-skilled players, batting performance was significantly better when attention was directed to an environmental/relevant cue (the flight of the ball leaving the bat) than when it was directed to an environmental/irrelevant cue (the tone). These results indicate that particular cues are more advantageous to successful performance than others.

Gray (2004) previously compared these two types of attentional cues using a baseball batting simulation and found that the performance of expert versus novice players was affected by which cues attention was allocated to. While expert performers suffered a decrement in performance in the skill-focused attention condition, the opposite was true for novice performers, whose performance decreased in the environmentally-focused attention condition. The observed differences in whether skill- or environmentally- focused attention is helpful or hurtful to performance can be explained by whether a motor task is carried out by either automatic or controlled processing.

Automatic vs. Controlled Processing. "How can you hit and think at the same time?" Yogi Berra's words imply that a lack of attention to skill execution may be associated with successful task performance (Beilock, Wierenga, & Carr, 2002). However, this notion may appear counterintuitive, as it seems that one must attend to performance in order to perform successfully. Several studies suggest that the execution of sport skill does not heavily depend on step-by-step monitoring and attentional control. Mental processing can operate in two different modes. In "conscious control" mode, mental processing is consciously controlled by intentions and draws on attentional capacity (Styles, 2006). In "automatic" mode, processing is a passive outcome of stimulation, and does not draw on attentional capacity (Styles, 2006). Rather, automatic processing is based on fast, efficient control procedures that can function largely without the assistance of working memory or attention (Castaneda & Gray, 2007). Once performance of a skill has become automatic, there is evidence that consciously "thinking" about it can actually reduce efficiency. The implication is that a task that once occupied a performer's attention can, after practice, be carried out faster and with less conscious effort and direction (Brown & Carr, 1989).

Several studies have suggested that attentional demands have different effects on automatized and non-automatized skills (Perkins-Cecato, Passmore, & Lee, 2003). Recently, Beilock, Carr, MacMahon, and Starkes (2002) explored the attentional demands involved in a soccer dribbling task at different levels of soccer expertise.

Novice and experienced soccer players dribbled a soccer ball, using either their dominant or non-dominant foot, through a series of pylons while simultaneously performing a secondary auditory monitoring task. Results demonstrated that the secondary auditory task harmed the dribbling performance of the less skilled players, regardless of which foot they dribbled with, yet did not affect experienced soccer players' dominant foot dribbling performance. However, when using their less practiced non-dominant foot, experienced players' dribbling did suffer from the dual-task condition. These findings suggests that while novel or less practiced performance may demand extensive attentional resources for successful implementation, such explicit monitoring and attentional control may not be necessary at high levels of skill execution. These experimental findings were reexamined in a study by Perkins-Ceccato, Passmore, and Lee (2003) using a golf pitch shot.

Using both highly- and low-skilled golfers, subjects in each group were asked to use a 9-iron to pitch a ball as close as possible to an orange pylon, which was located at four different distances from the golfer. Focus of attention was manipulated within participants. Participants were told to either concentrate on the form of the golf swing and to adjust the force of their swing depending on the distance of the shot (internal focus) or to concentrate on hitting the ball as close to the target pylon as possible (external focus). Results showed that the highly-skilled golfers performed better with external attention instructions and the low-skill golfers performed better with the internal focus of attention. Similar results were found by Beilock, Bertenthal, McCoy and Carr (2004). Novice and expert golfers took a series of putts under two conditions; a dual-task condition designed to distract attention from putting and a skill-focused condition that prompted attention to step-by-step performance. Novices performed better under skill-focused than under dual-task conditions while experts showed the opposite pattern. Therefore, similar to skills in other sports, once the fundamentals of the golf shot have been learned well, performance becomes “automatic” and benefits more by focusing attention to a secondary or external task rather than the procedures of the skill itself.

Beilock, Wierenga, and Carr (2002) also explored the attention processes governing a golf putting task. Novice and experienced golfers were asked to putt in a single-task and dual-task condition. Experienced golfers did not differ in putting accuracy from single- to dual-task conditions. Also, compared to novices, experienced golfers had higher performance scores on the secondary auditory word search task. However, when using an s-shaped weighted “funny putter” designed to disrupt the automatic mechanics of skill execution, experienced golfers decreased dual-task putting accuracy and secondary task performance. The unfamiliar putter disrupted automatic skill execution, demanding an increased level of attention to be devoted to the putting task, and compromising secondary task performance.

After a kinematic analysis of batting mechanics, Gray (2004) found similar results among athletes asked to hit a baseball. Gray (2004) explained that the underlying mechanism for his and others’ findings was partially due to the fact that skill-focused attention interfered with the sequencing and timing of the motor responses involved in the particular sport skill. On the other hand, while environmental cues such as auditory noises (irrelevant to performance) should be beneficial for expert performers because they allow proceduralized knowledge to operate uninterrupted, they should be equally detrimental to novice performers because they draw attention away from skill execution (Beilock, Carr, MacMahon, & Starkes, 2002; Castaneda & Gray, 2007). Using this information, we can expect that a dual-task setup has different effects depending on both level of expertise and the type of attentional styles individuals exhibit during free throw shooting.

According to this explanation, skilled players should focus on environmental rather than skill information. Although any environmental task would prevent the interruption of procedural knowledge, Castaneda and Gray (2007) explain that an environmental attentional cue such as watching the ball leave the bat, has an advantage in that it still provides a connection to the action, rather than only attending to an irrelevant stimulus such as an auditory tone. Nevertheless, when interpreting the difference between the two attentional conditions, there is an important caution that must be noted. Not only do batters attend to different information, but they also attend at different times during the action. Where one condition required subjects to direct attention during the swing, the other condition requires subjects to direct attention to an event after the swing is complete. Therefore, it is possible that batting performance was better in the environmental condition not because there is an advantage in attending to the skill, but rather because the batter's attention was "freed-up" during swing execution (Castaneda & Gray, 2007). Brown and Carr (1989) note a similar idea; that attention switching would not be feasible if both tasks imposed demands that were heavy and constant. However, in a dual-task setup, as the demands of one task decrease, the ability to switch attention to the second task is made possible. It is the constant switching of attention between tasks that makes dual-task performance possible, not the ability to direct full attention to both tasks simultaneously.

Gray and Beilock (2007) had similar findings when examining the role of expertise in attentional control in golf putt execution. Novice and experienced golfers were asked to putt in a skill-focused condition in which participants judged whether the tone occurred closer to the starting or end point of a particular swing segment in which the tone was presented. For both novice and expert golfers, putting accuracy was degraded during this dual task. However, for experts, performance was significantly worse when the tone was presented earlier in the stroke. Again, similar to Castaneda and Gray's findings, Gray and Beilock found that varying degrees of attentional demand exist during the execution of a golf swing. For this reason, the effects of secondary tasks on performance should be compared to the time course of attention of the particular motor skill being investigated.

Evidence shows that high-level performance appears to be governed by proceduralized knowledge that does not require constant attention and, indeed, can be harmed by it (Beilock, Carr, MacMahon, & Starkes, 2002; Styles, 2006; Perkins-Ceccato, 2003). As a result, experienced individuals performing under normal, practiced conditions are better able than novices to allocate a portion of their attention to secondary task demands. Conversely, novel performance processes appear to be based on knowledge that requires active attention and information processing (Beilock, Wierenga, & Carr, 2002; Styles, 2006). As a result, novice performers are not able to adapt to the demands of dual-task environments, showing decrements in both primary and secondary task performance in comparison to performance of either task in an isolated, single-task environment. The findings of these studies suggest that the detrimental effects of dual-task performance might be greater for low-skill athletes than for high-skill athletes because the performance of skills are less 'automated' than that of high-skill athletes. Despite this information, we believe that even highly automatic skills demand some central capacity, and therefore, are subject to dual-task interference.

While information on automatic and controlled processing would suggest that a secondary auditory tone would impact subjects differentially based upon their expertise and experience with the primary task, researchers must be careful not to overlook findings of dual task studies (Land & McLeod, 2000; Prezuhy & Etnier, 2001; Sibley & Etnier, 2004) that have shown that attentional demands of a particular task may not be linear. Therefore, the importance of what cues we focus on should not overshadow the importance of when we focus on those cues. As in the Castaneda & Gray (2007) study, it would be inappropriate to assume that the timing of the different conditions relative to the baseball swing did not impact performance results. We must first assess the time course of attention relative to expertise in a task before we can make conclusions about why certain cues have different effects on performance. Information regarding the time course of attention can be gathered using the reaction time probe technique.

The Reaction Time Probe Technique

In the motor learning literature, the attentional demands of any given task can be assessed in a dual-task method using a reaction time (RT) probe technique (Prezuhy & Etnier, 2001). Based on the capacity theory, this particular 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 (Prezuhy & Etnier, 2001). Thus, RT performance will suffer so that primary task performance can be maintained. Castiello and Umilta (1988) used this technique to document the time of peak attention in several sport tasks; a volleyball service reception task, 100 meter dash, 110 meter hurdles, and a tennis service reception task. In both the tennis and volleyball reception task, Castiello and Umilta found that all stages of the return were demanding of attention in that there was an increase in RT with respect to the control. Reaction time was slowest just as the ball landed in the near court and was a little faster just as the ball was being received. In addition, in the tennis and volleyball reception task, probe positions 1 (when opponent was about to serve) and 2 (when ball was above the net) were least demanding of attentional resources and exhibited the fastest reaction times. Castiello and Umilta's results also found that the 100 meter dash and the 110 meter hurdles displayed results similar to each other. Reaction times were slower at the beginning and at the end of the race than at the intermediate times. This was the first time peak of attention of a real-world sport task had been observed at a specific point in the movement (Castiello & Umilta, 1988). This study also showed the value of the RT probe technique when examining the time course of attention of a particular task.

Prezuhy and Etnier (2001) used the RT probe technique with the primary task of pitching horseshoes as closely as possible to a target stake. Two levels of task difficulty (easy, difficult) were created by manipulating the height of the target stake. The secondary task was to respond as quickly as possible to an auditory tone via the response device held in the pitcher's non-throwing hand. Secondary task performance was measured as 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. Results indicated that RTs at all probe positions were slower during the difficult task than during the easy task, indicating that a greater portion of the individual's limited attentional resources were devoted to the primary task in the difficult condition. Similar to Castiello and Umilta's results, Prezuhy and Etnier found 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 (when throwing hand reaches its farthest extended position behind the body) and slower at PP1 (when initiating movements begin) and PP3 (point just prior to horseshoe release), suggesting 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) (Prezuhy & Etnier, 2001).

In certain ball-sports such as volleyball, tennis, and baseball, focusing attention on appropriate cues during ball flight is important to determine the timing of contact with it. However, in basketball, visual focus is often important in determining the trajectory of the ball after the ball has left the hands. Compared to measures of attention on cognitive tasks or to auditory stimuli, visual attentional focus can also be measured with a head-mounted eye camera. A camera of this type records the view from one specific eye, as well as the direction of the foveas's gaze. Information from this method substantiates results from the reaction time probe technique. Using this approach, Land and McLeod (2000) found that the eye movements of cricket batsmen do not follow the ball continuously, but only view the ball at crucial moments during its flight. They fixate on the ball as it is delivered, at the time of the bounce, and for a period up to about 200 ms after the bounce. Therefore, we see that similar to many others' findings, information processing is not continuous. Rather, particular points of time require a greater demand for attention than others (Sibley & Etnier, 2004; Prezuhy & Etnier, 2001; Castiello & Umilta, 1988). However, we do not see this curvilinear pattern of attentional demands in all motor tasks. Rose and Christina (1990) found that reaction time to an auditory tone increased in a near linear fashion during a pistol shooting task. Therefore, they concluded that the demands on attentional capacity increased as the actual time of the shot approached.

Consequently, it is not critical that attention goes uninterrupted or is never divided between environmental cues, but that we do our best to allocate the necessary resources to the primary task when demands for those resources are required and essential to successful performance. However, according to the literature and Capacity Theory, when attentional demand is not at its peak, there is a greater "reserve" for secondary information to be processed. Therefore it is possible for us to carefully share resources and still be successful at multiple tasks. Studies using the reaction time probe technique have provided us with useful information as to when attention to ball flight must be "primary." By using this technique to examine attentional demands of tasks within different sports, we may find that categories of sport skills emerge that show similar patterns of attentional demand (Prezuhy & Etnier, 2001). Therefore, while individual sports utilize different motor tasks and skills, we may be able to categorize motor tasks across different sports that show similar attentional characteristics and give athletes and coaches information critical in the development of appropriate attentional focus.

The Capturing of Attention

Unintended capture is applicable to sport because of the multitude of distractions, both relevant and irrelevant to performance, that athletes do not expect but inevitably captures and uses their limited attention. Although research using the dual-task paradigm in sport has been successful in measuring the time course of attentional demands for a given task, this research fails to describe how secondary stimuli capture attention in the first place. When individuals are focused on a particular task it is difficult to understand why attention is so susceptible to distractions. There are many theories or hypotheses that explain how multiple stimuli capture attention and affect task performance. Attentional capture is described as a means by which previously unnoticed information becomes conscious and available to information processing (Horstmann, 2006). The surprise-capture hypothesis (Meyer, Niepel, Rudolph, & Schutzwohl, 1991) states that a stimulus has the ability to capture attention even if it does not match the control settings, implying unintended capture. Therefore, according to this hypothesis, we can predict that unexpected incoming stimuli, such as noise from the crowd during a free throw, will cause an attentional shift and strongly affect accuracy of performance.

One domain for studying attentional capture has been the localization of a singleton in a visual search task. A singleton is defined as a stimulus that differs on a basic perceptual dimension such as color or size, from its surroundings (Horstmann, 2006). In visual search tasks, several stimuli of the same type are presented together, and the observers' goal is to search for specified targets. Horstmann (2006) tested the surprise-capture hypothesis by systematically varying the preview duration of a set of singletons. Horstmann found that SOA strongly affected accuracy with the unexpected singleton, finding a delay in reaction time due to the triggering of an attentional shift. Therefore, results are interpreted as supporting the surprise-capture hypothesis. These findings have important implications in sport in that an attentional shift to unexpected stimuli and events causes a delay in reaction time that can be significant to performance.

Although there is a great deal of literature on the kinematics, biomechanics, and physics of basketball shooting, no study has isolated a single quality that improves shooting performance (Vickers, 2007). As individual attention shifts to previously unnoticed information, fixation on the primary task becomes compromised. During the preparation of an accurate free throw shot, attentional gaze is directed to a single location on the hoop and fixation is maintained on that location for an optimal duration (Vickers, 1996). It does not matter which location is fixated as long as only one target location is the focus of visual attention. It has been found that elite shooters have a lower frequency of fixations during each shot than do novices or near-elite athletes, and the number of fixations is lower on accurate shots than on inaccurate shots (Vickers, 2007). Because a shift in gaze is preceded by a shift in attention, it seems that elite shooters not only control their gaze with more precision, but also focus attention on only one location during each shot (Vickers, 2007). Therefore, by isolating our study to the attentional load placed on the free throw shooter, we can identify those phases of the free throw that require the greatest attentional fixation. Knowing this information, we may be able to identify specific ways to train free throw shooters to focus attention and maintain fixation on a target in order to improve shooting performance.

Conclusions

In the realm of sports, the mind must focus on a primary task while sorting through other forms of information that compete for the brain's already limited resource capacity. Through time, basketball has evolved into a complex game with many interrelated elements that require great physical and cognitive skill, as well as a great deal of decision making. Players must make decisions as to what information they give priority to, and what they dismiss as irrelevant and distracting. As a result, attentional resources are constantly being used. However, because of the interactive nature of the game, multiple incoming stimuli, either relevant or irrelevant to performance, challenge an individual's ability to organize and process incoming information and manage dual-tasks, pushing attentional capacity to the limit.

The basketball free throw is a critical skill necessary for successful performance in the sport of basketball. As the name implies, the shot takes place on a line 15 feet from the basket, and "free" from defenders. Because of its nature, one would assume the free throw would be the one skill in basketball least likely to be affected by distractions. However, because the shooter is singled-out from all other players, oftentimes this isolation makes the shooter more vulnerable to and often the target of attentional distractions, particularly auditory distractions that are unexpected and irrelevant to performance.

The free throw is characterized by a set of movements that must be done with careful precision to succeed and score points. Opponents, fans, coaches, and oftentimes your own thoughts compete for the same attentional resources, which are limited in capacity. By measuring the attentional demands at different points during the free throw we can make inferences as to the points at which attention to the task is most critical. While rules do not preclude visual distractions, the use of an auditory cue in this study prevents the structural and content-dependent interference discussed and proposed by early psychologists, which occurs when concurrent tasks involve the same response system. In addition, the use of an auditory cue to measure attentional demands of the task maintains ecological validity because while the athlete may be able to maintain visual focus on the target, the barrage of auditory stimuli is the most harmful type of distraction that the isolated shooter can expect to face.

Vickers (1996) looked at the control of visual attention during the basketball free throw in order to determine what the eyes should fixate on during both shot preparation and execution. She recorded eye movements (gaze behaviors) of 8 expert and 8 non-expert athletes to understand the role of visual attention during the free throw. They divided the free throw into four movement phases: (1) Preparation (before the ball moved into shooting action), (2) Pre-shot (initial drop of the ball and before the upward shooting action), (3) Shot (the first upward motion of the ball until the ball leaves the fingertips), and (4) Flight (after the ball leaves the fingertips and contacts the hoop or backboard). Vickers found that not only was experts' gaze behavior steadier during the preparation and pre-shot phase, but those near-experts with the lowest shooting percentage exhibited fixation instability alternating from hoop to backboard within a trial. Another important finding was that as the ball entered the shooter's visual field, fixation offset, which prevents the intake of interfering information from the moving hands and ball in the visual field, occurred earlier in the experts. From this information we understand that shooters should fixate on their target for a longer duration as they prepare the shot and then, as the shot is initiated and the ball enters the visual field, they should suppress vision. By examining the gaze behavior in four different movement phases, Vickers documented the importance of the control of visual attention in the performance of free throws. We now understand that the steady control of visual attention during the preparation and pre-shot phases differentiates athletes into "expert" and "non-expert" shooters. Must attention be steadier during these phases because they require the most attentional demand? Does fixation offset occur during the time of lowest attentional demand? I hope to find whether these attentional patterns are related to attentional demands of each separate phase, and if the ability of an individual to perform the task successfully depends on their ability to display the appropriate attentional processes at the proper times.

In light of both the importance of the free throw in basketball success and past literature examining the mechanisms by which attention is disrupted, the purpose of my study is twofold. Using the dual-task paradigm, I hope to 1) determine the effect of a secondary auditory-tone task on the primary free throw task performance. In addition, by applying the Capacity Theory and using the well-established reaction time probe technique, I hope to 2) determine the time course of attention of the basketball free throw and assess the allocation of attention to the performance of multiple tasks.

CHAPTER III

METHODOLOGY

Research Design

An experimental, repeated measures design was used to study free throw performance and RT during a dual-task setup. Because this is a within-subjects design, baseline performance scores serve as a "control." The independent variable is timing of auditory tone (probe position). The dependent variables are free throw performance and verbal reaction time to an auditory tone. The auditory tone was presented at four different probe positions to test the attentional demand at different points of the free throw process. In addition, catch trials, where no tone is administered, were included within the secondary task condition to eliminate anticipatory effects.

Participants

Participants consisted of 30 individuals (4 females, 26 males), ranging in age from 18 to 62 (mean age of 23.9 $\pm$ 8.3 years). Twenty-seven of the participants ranged in age from 18 to 28 years. The three remaining participants were 30, 37, and 62 years of age. Each participant had at least two years basketball experience at the high school level. Participants of a similar experience level increased internal validity by controlling for differences in task familiarity and skill. Also, in light of the research by Beilock and colleagues on the differences between novice and expert athletes in attentional cues most beneficial to performance, recruiting participants of similar skill can reduce discrepancies between subjects of varying experience. All participants filled out short questionnaires about their basketball experience prior to the beginning of the study. The number of years participants had been active in any basketball related activity ranged from 3 to 52 years, and the number of years which participants had been inactive from competitive basketball at the time of the study ranged from 30 years to those who were currently active (0 years). Playing experience for participants ranged from Junior Varsity (n=2) to Varsity (n=14) and College (n=14). All signed an informed consent before participating.

Measures/Instrumentation

Basic facilities and equipment included a gym with a standard basketball backboard and goal, one basketball, and individuals to perform the following roles: (1) rebounder/scorer and (2) tone administrator/sound recorder. The experiment took place in a gym with a free throw line marked at the regulation NCAA and high school distance of fifteen feet from the backboard.

Specific equipment was needed for the measurement and analysis of primary and secondary task data. An auditory tone was used to test reaction time in this particular study for three reasons. First, with the nature of the free throw task, visual attention must be focused on the target. Therefore, reaction to a visual stimulus would direct attention away from the intended target, affecting shooting performance. Secondly, many researchers have confirmed that reaction to sound is faster than reaction to light, with average reaction times to auditory tones being 20-60 ms quicker than reaction times to visual information (Kosinski, 2006). This is thought to be due to the fact that an auditory stimulus only takes 8-10 ms to reach the brain, while a visual stimulus takes 20-40 ms

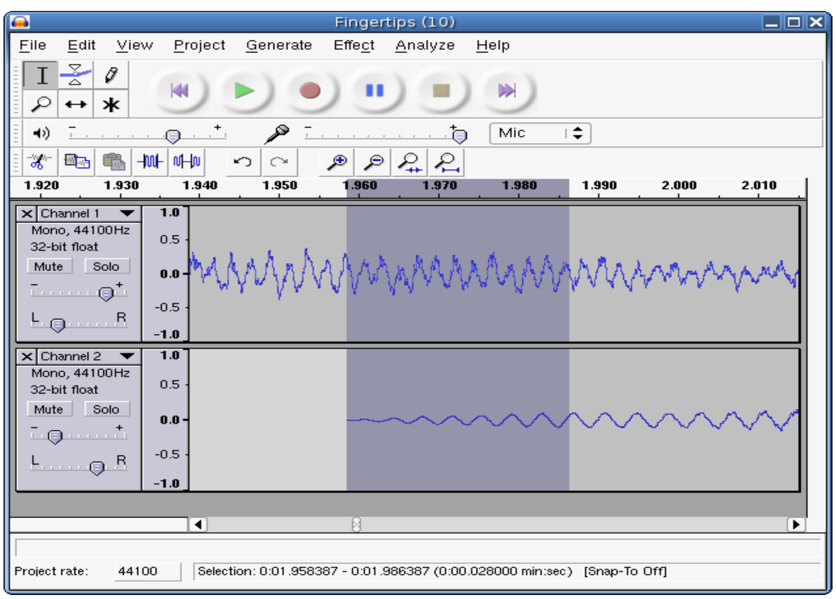
(Kosinski, 2006). Lastly, the reaction time probe technique, which utilizes auditory tones to measure reaction time at different probe positions has been used and validated by researchers examining the attentional demands of different sport tasks.

Because of the nature of the experiment and the need for tones to be administered at specific probe positions that are unique to each individual, auditory tones were controlled by the experimenter. The tone, which was downloaded through the Windows software, was administered by manually pressing play on the iTunes program. The tone played immediately through speakers attached to a laptop computer and lasts .915 seconds. As in the Prezuhy and Etnier (2001) study, the use of a speaker system helped to maintain ecological validity because environmental noise from spectators and other background noise are common in basketball, especially during free throws.

In addition, digital videotaping with frame-by-frame breakdown capability was used to ensure that tones were presented at the four specific points of analysis. Following each free throw session, the investigator examined the videotapes to ensure that each tone was presented in the defined probe position time (See Table 1). If the investigator found that a particular tone was not administered within the defined beginning and end of each probe position, the average of the other trials for that specific probe position (1, 2, 3, etc.) was used for this one particular trial. If more than two tones in a specific probe position were incorrectly administered, that subject's data were thrown out.

In addition to the video equipment, auditory equipment was needed to detect both the tone and the participant's verbal response to measure and record reaction time. Audacity (version 1.2.6) audio editor and recorder was used to record both the auditory tone and the verbal response from the subject. A microphone that clipped to the subject's shirt picked up sound and sent a signal to a voice-activated relay mechanism to measure and record reaction time. A built-in spectrogram and the "plot spectrum" allowed for detailed frequency analysis. Figure 1 shows a screenshot of Audacity running on the computer screen. After individual recordings from all trials are collected, Audacity allows each waveform to be zoomed so they are more pronounced. In addition, the speed of the audio playback was slowed by 20% of original speed so that the investigator could pinpoint the exact point of each sound. Audacity automatically displays the amount of time elapsed between any two given waves, making data analysis more accurate. Therefore, by placing the cursor on the wave representing the auditory tone, then dragging to the wave representing the vocal response, reaction time was measured up to more than 1/1000 of a second.

Figure 1: Audacity Recording



Procedures

Individual sessions were arranged for each participant. Each participant performed only one session, which took approximately 20 minutes, including arrival, briefing, warm-up, and the experiment. The experiment took place in either the research gym or reserve gym at The University of North Carolina at Greensboro. Subjects were first briefed as to what they could expect during the study, the number of shots they would be taking, and instructions for their response to the auditory tone. Participants were then asked to sign the informed consent form before beginning. Participants were also asked to fill out a short questionnaire about their basketball experience.

For the experimental task, participants began at the free throw line. Each shooter was first asked to respond to the auditory tone as quickly as possible by saying "ball." The average reaction times of these five trials, which did not include a ball, served as a baseline RT score. Immediately following the baseline RT trials, the subject received a bounce pass from the rebounder/scorer, who was standing 15 feet in front of them prior to each shot. Participants were given five warm-up free throws, which were not scored. Following the five warm-up free throws, subjects shot 10 free throws that were not interrupted by the auditory tone. Although reaction time was not measured during these trials, the shooter wore all auditory equipment (microphone) so shooting conditions remained stable across the entire experiment. All shots were scored, however, and performance on 8 (chosen randomly by the investigator) of the ten shots comprised the baseline measure used for analyses. A shooting percentage based upon eight shots was assumed to be a reliable representation of free throw performance. Only data from those participants who shot a baseline performance of 50% or greater were used for analysis. This was to ensure that participants were, at baseline, moderately to highly-skilled free throw shooters and any poor performance observed during the secondary task condition was not due to a lack in skill.

Scoring was based on complete miss (0 points), near miss (ball hits rim) (1 point), or make (2 points). As previously described, points from eight of the ten baseline shots were averaged to create a baseline performance score. Participants were then asked to complete the same free throw task concurrently with a secondary, auditory reaction time test. At this time, participants were reminded to treat the free throw shot as the primary task, assigning it the most attentional weight. Participants were asked to do as well as possible on the primary task and, given that constraint, as well as possible on the secondary task. Participants were also told that catch trials, where no tone is sounded, would be integrated within secondary task performance at random.

The basketball free throw is characterized by a pre-shot routine that is unique to every individual. This becomes problematic when trying to identify specific probe positions that are common to every shooter. While one individual may focus on the target immediately after receiving the ball, another may not focus on the target until just before the ball leaves the shooter's hands. However, the investigator was able to identify four probe positions that could be visually identified within some point of the free throw process. Although the shooter was allowed to use whichever pre-shot routine he/she felt most comfortable with, they were asked to use the same routine prior to each shot.

Varying levels of complexity across different pre-shot routines were not expected to impact results because participants were asked to use the routine they felt comfortable with.

The auditory tone was administered at four different probe positions during the free throw process (1) preparation, (2) pre-shot, (3) shot, and (4) flight. These probe positions are described in more detail in Table 1. During the "secondary" phase of the experiment, the tone administrator administered eight tones at each probe position. Eight catch trials were also included for a total of 40 shots. The random order of tones was set prior to the experiment. Just as in the baseline RT trials, participants were asked to respond to the tone by yelling "ball" as quickly as possible. As suggested by both Prezuhy and Etnier (2001) and Sibley and Etnier (2004), catch trials, where no tone is given, were included to eliminate anticipation effects on performance. To establish inter-observer reliability, a second observer examined each trial for a random subject to ensure that the investigator had appropriately administered the tone at each probe position according to its stated definition, and the investigator had properly measured reaction time according to its stated definition.

The time of peak attentional demand was determined by the point of time (probe position 1, 2, 3, or 4) at which reaction time was significantly slowest. At the same time, to examine the effect of this dual-task on performance, the original scoring method for free throw performance continued to be implemented so that scores would be compared between primary and secondary task conditions. Additionally, free throw performance on the catch trials was compared to baseline free throw performance to ensure that the mere inclusion of the secondary task did not impact primary task performance. A summary of the number of shots and the measurements at each stage of the experiment are presented in Table 2.

Table 1: Probe Positions

Probe #	Probe Name	Probe Description
1	Preparation	After catching the bounce pass and before the first upward motion of the ball (during pre-shot routine)
2	Pre-shot	The first upward motion of the ball – before ball reaches chest level
3	Shot	The remaining upward motion of the ball - until the ball leaves the fingertips
4	Flight	Immediately after the ball leaves the fingertips and before contact with the hoop/backboard
5	Catch	No tone is sounded – Used to reduce anticipatory effects

Table 2: Summary of Measurements

Stage	Warm-up	BL RT	Primary Task	PP1	PP2	PP3	PP4	Catch Trials
# of shots	5	5	10	8	8	8	8	8
Performance	-	-	Yes*	Yes	Yes	Yes	Yes	Yes
RT	-	Yes	-	Yes	Yes	Yes	Yes	-

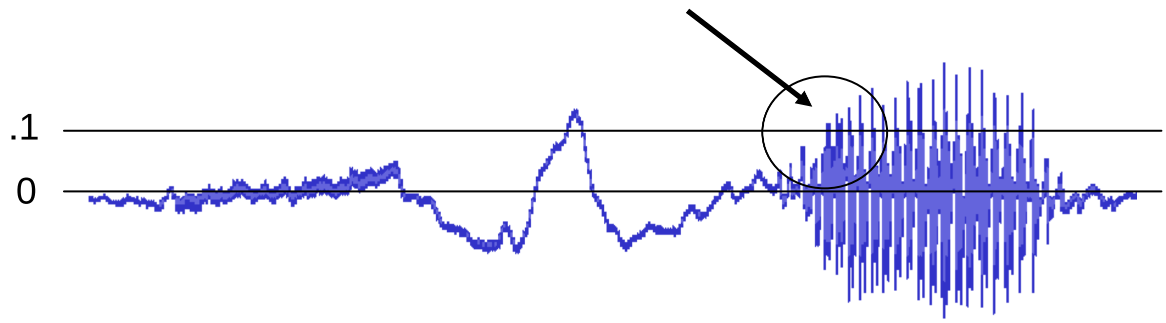
BL = Baseline
PP = Probe Position
RT = Reaction Time
Pf = Performance
* Only eight of the ten used for baseline performance score

Analyses of data

For each subject, the investigator first replayed the digital video recording of each trial in which a tone was presented. The video was replayed on Windows Media Player at a slowed speed to allow the investigator to ensure that each tone was administered at the intended and defined position. Of the eight tones played at each probe position, only two errors at each position were allowed. If a particular tone was not played within its defined parameters, the average of the remaining correct tones was used in place of the incorrect tone.

For this study's purposes, reaction time is defined as the time from the beginning of the auditory tone to when the verbal response reaches a waveform amplitude of 0.1 dB. All recorded data were analyzed through the Audacity program. Recordings were first enlarged for a more detailed waveform analysis. The beginning of the auditory tone (the start time of our reaction time measurement) was distinguished by visual and aural identification of a burst in waveform activity. The beginning of the verbal response was identified by using envelope editing, a tool provided by the Audacity program that automatically marks a waveform amplitude of 0.1 dB for each trial. A vertical ruler for each recording in the Audacity program is displayed as a guide to waveform levels. The point at which the waveform representing the verbal response first intercepts a waveform value of 0.1 dB is used as the ending time of our reaction time measurement. Figure 2 gives an illustrative description of how these data were derived. This type of analysis made reaction time measurement more objective, and less susceptible to investigator bias.

Figure 2: Measuring Verbal Reaction Time



To prevent errors in transcription, the investigator directly entered both the start and end time of the reaction time measurement from the Audacity program into an excel spreadsheet. Values were automatically rounded by the computer program to one ten-thousandth of a second. In addition, to avoid possible researcher bias in data analysis, the investigator entered data into an excel spreadsheet that did not display the order in which recordings were presented. Therefore, the investigator was not aware which probe position she was analyzing and entering data for. A secondary observer analyzed both video and reaction time data for one subject in the same manner as just described to establish reliability of data measurement between different observers. For the inter-observer reliability check for both the video and Audacity data, the investigator looked for at least 90% agreement between the principal investigator and secondary observer.

According to the reaction time probe technique, attentional demand of the primary task cannot be properly assessed based upon secondary task performance if the primary task is not given the most attentional weight. Therefore, it is important to ensure that the free throw performance is of primary importance and maintained throughout the experiment (Prezuhy & Etnier, 2001). If a decrease in primary task performance is observed when the secondary task is introduced it is inappropriate to use the theory behind the reaction time probe technique because performance on secondary task performance is used to assess the attentional demands of the primary task. Therefore, if participants reprioritize the primary and secondary task, reaction time becomes the primary task and we cannot correctly test our hypotheses (Prezuhy & Etnier, 2001). To check that primary task performance was maintained during the experimental trials, ANOVA with repeated measures was used to compare primary task performance at baseline with primary task performance during experimental trials. Specifically, a one-way ANOVA with six levels (performance during the baseline trials, the four probe positions, and the catch trials) was used to compare performance scores across probe positions.

To examine the time course of attentional demands, RT was examined using another one-way ANOVA with repeated measures. Because the auditory tone was sounded eight times at each probe position, the average of these eight trials was used as the dependent measure in the one-way, within subjects ANOVA with 5 different levels (each of the 4 probe positions and baseline RT). Tests of simple and repeated contrasts compared conditions to show which conditions differ from one another following a significant overall F for conditions.

Expected Results

Based on key literature in the field that has focused on using the dual-task paradigm to determine the attentional demands of motor tasks, results comparable to other sport-related tasks were expected. Using the dual-task paradigm, the limits of information processing during free throw shooting were tested by asking participants to complete a primary task concurrently with a secondary task. The two primary expectations were: (1) participants will treat the free throw as the primary task throughout the entire experiment and therefore assign the task the most attentional weight; thus, the introduction of the secondary task will not decrease performance as compared to baseline scores, and (2) those points of the free throw process that require the greatest attentional demand will take up more central processing space, causing decreased performance and slower RT on the auditory reaction time task. In particular, I expected the slowest reaction times during probe position 2 (pre-shot) and 3 (shot), when the shooter's attention is directed to kinesthetic movement. I expected that attention to the position of the limbs is critical to carry out precise muscle movement and maintain technique in order to make a shot. In addition, according to Vickers (1996), a steady attentional gaze is most critical during the preparation phase of the free throw. Therefore, I expected probe positions 2 and 3 to demand high amounts of attention for the maintenance of visual fixation upon the target.

CHAPTER IV

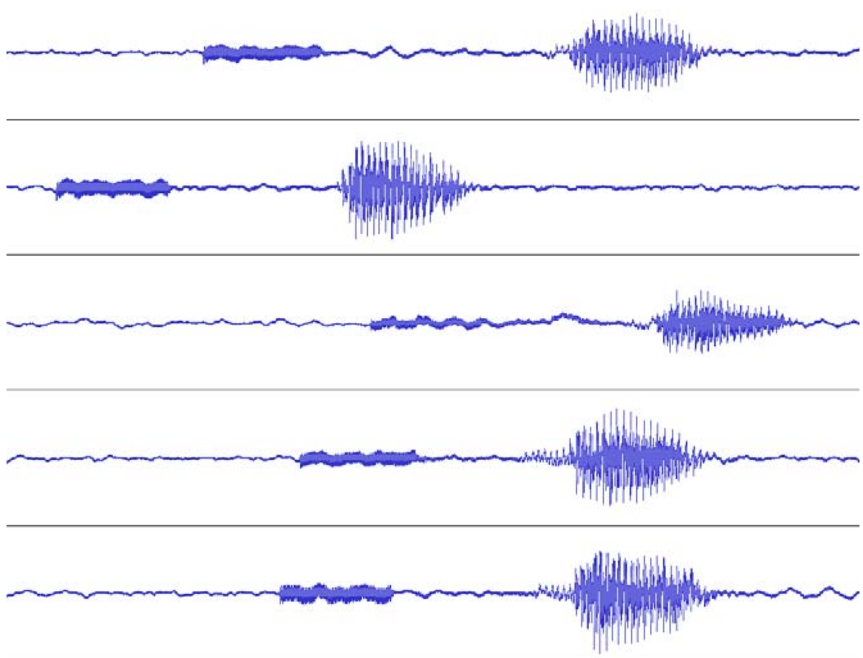
RESULTS

This chapter presents the results of the analysis of data on reaction time and free throw performance. The first section presents examples of reaction time recordings, indicating the confidence and reliability at which reaction time could be measured. Separate repeated measure ANOVAs were used to determine how the timing of the auditory tone affected both performance and reaction time. A test of simple contrasts then revealed differences in performance and reaction time compared to baseline scores. Finally, to examine whether differences in basketball experience affected the dependent variables, a two-way mixed ANOVA was used. Participants were grouped according to the level of basketball experience, the number of years they had been active in a basketball-related activity, and the number of years they had been inactive from competitive basketball at the date of the study. Results for both within- and between-subject analyses are provided in this section.

Example of Reaction Time Recordings

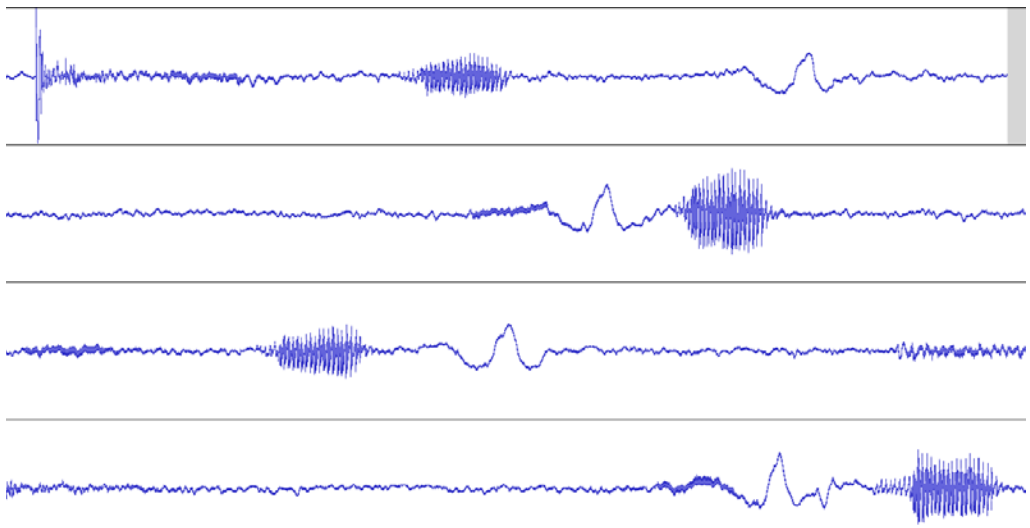
Figures 3 and 4 show representative samples of the Audacity recordings used to derive reaction time data. Each subject had 37 trials that were analyzed (8 trials for each of the four probe positions and five baseline reaction time trials). All subjects met the 50% baseline performance minimum requirement except for one, whose data was not included. Figure 3 shows recordings from the baseline reaction time test for Subject 22. Figure 4 shows recordings from the dual-task conditions for Subject 5. As the figures indicate, dual-task recordings had a greater amount of background "noise," which was due to the sound of the ball bouncing, movement from the participant, etc. While background noise made it more difficult to pinpoint the increase in waveform amplitude due to the sound of the auditory tone, this location could still be identified with confidence by using both visual and auditory evidence to accurately identify the first point in reaction time measurement.

Figure 3: Baseline Reaction Time Recordings



*Subject 22

Figure 4: Reaction Time Recordings During Dual-Task Performance



*Subject 5

Inter-observer Reliability

To verify that the analysis of reaction time data was reliable, a second observer was asked to record reaction time data following the same guidelines used by the investigator for every trial of a single subject. Total reaction times for each trial from both observers were then compared. Intraclass correlation showed that the measured reaction times between observers were highly reliable (interval of .967 to .991 with 95% confidence). This suggests that the guidelines for analysis put forth by the investigator were appropriate for measuring reaction time in an unbiased manner and scores can be reliably reproduced by other observers. In addition to reliability in reaction time measurement, a second observer also reviewed video-taped data to ensure that each tone was administered in the intended and defined probe position. The second observer was in

93.75% agreement with the investigator over 32 trials for a single subject, with the investigator being stricter in scoring. Overall, the investigator was accurate in administering the tones within their defined probe positions. Of a total of 960 trials (32 tone-administered trials x 30 subjects), only 22 tones (2.3%) were misplayed and the average of the remaining correct trials was used to replace these data. The breakdown of incorrect tones is as follows: PP1 – 7, PP2 – 10, PP3 – 3, PP4 – 2. No subjects' data had to be thrown out due to investigator error on tone administration.

Performance

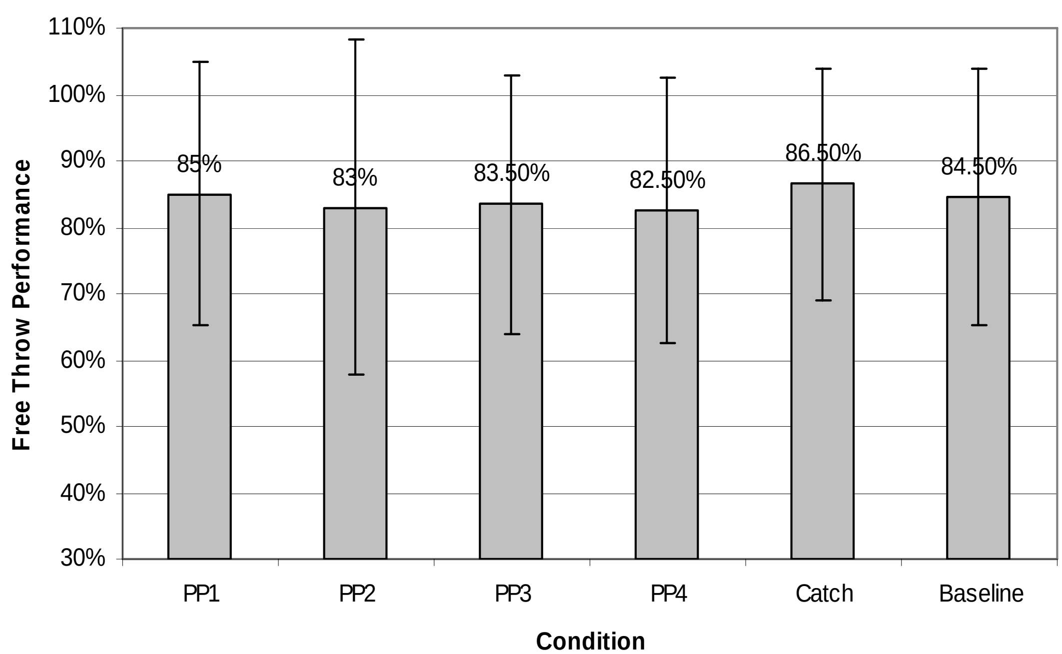
Repeated measures analysis showed that overall, there is no significant difference in performance as a function of condition (probe position), $F(5, 145) = .870$, $p > .05$, $\eta^2 = .029$. Table 3 shows the mean and standard deviation of performance for all conditions. A test of simple contrasts showed that free throw shooting performance at any of the four probe positions was not significantly different from baseline performance. This suggests that participants were able to keep the free throw as the primary task, assigning it the most attentional weight. Figure 5 gives a graphical presentation of free throw performance across conditions. Given these results, with the dual-task paradigm, we can assume the free throw task was assigned the most attentional weight and any increases or decreases in reaction time performance across probe positions can be attributed to an increase or decrease in attentional demand, respectively.

Table 3: Influence of Condition on Free Throw Performance

Condition	Minimum	Maximum	Mean	% Performance	Std. Deviation
PP1	1.375	2	1.70	85%	.1986
PP2	1.125	2	1.66	83%	.2520
PP3	1.250	2	1.67	83.5%	.1955
PP4	1.125	2	1.65	82.5%	.2008
Catch	1.250	2	1.73	86.5%	.1740
Baseline	1.380	2	1.69	84.5%	.1930

N = 30

Figure 5: Influence of Condition on Free Throw Performance



Reaction Time

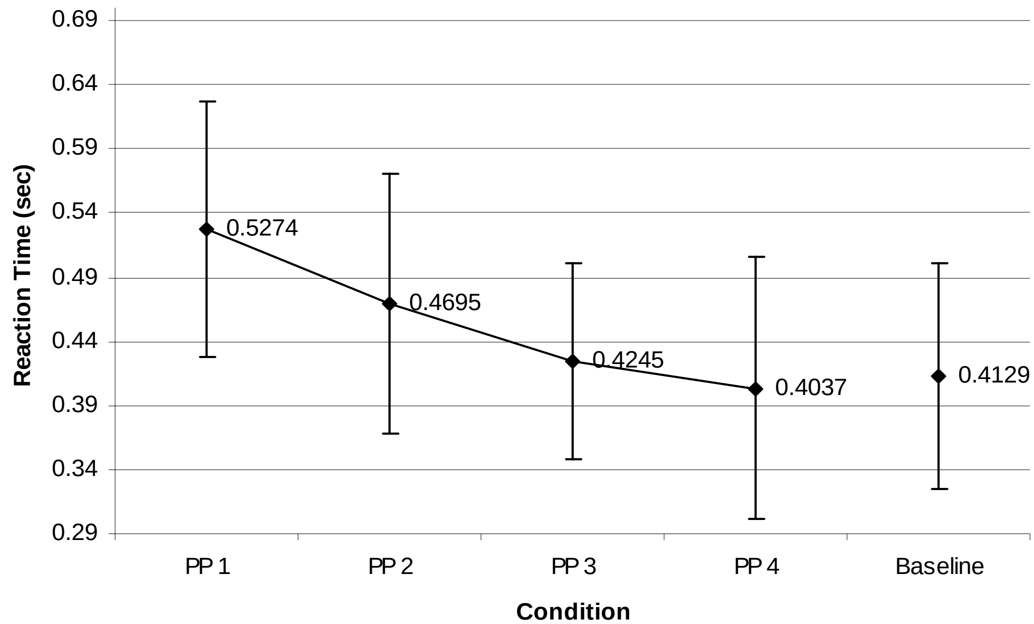
Repeated measures analysis showed an overall significant difference in reaction time as a function of condition, $F (4, 116) = 20.79$, $p < .05$, $\eta^2 = .418$. Table 4 shows the mean and standard deviation of reaction time for all conditions. A test of simple contrasts showed that reaction time at PP1, $F (1, 29) = 38.23$, $p < .05$, $\eta^2 = .569$ and PP2, $F (1, 29) = 8.56$, $p < .05$, $\eta^2 = .228$ was significantly higher than baseline reaction time. In addition, a test of repeated contrasts showed that reaction time on PP1 was significantly higher than PP2, $F (1, 29) = 12.86$, $p < .05$, $\eta^2 = .307$ and reaction time at PP2 was significantly higher than reaction time at PP3, $F (1, 29) = 16.96$, $p < .05$, $\eta^2 = .369$. Figure 6 illustrates the effect of condition on reaction time. According to the dual-task paradigm, these results suggest that the pre-shot routine (PP1) requires the greatest attentional demand, followed by the first upward motion of the ball. In addition, these results indicate that following the first upward motion of the ball (PP2), the remaining free throw requires no more attention than required for the baseline reaction time task, also suggesting that after a particular point the free throw is carried out automatically and uses a minimal amount of attention.

Table 4: Influence of Condition on Reaction Time

Condition	Minimum	Maximum	Mean	Std. Deviation
PP 1	.3421	.7735	.5274	.1001
PP 2	.3146	.7049	.4695	.1009
PP 3	.3149	.5965	.4245	.0756
PP 4	.3088	.8004	.4037	.1024
Baseline	.2554	.6461	.4129	.0881

N = 30

Figure 6: Influence of Condition on Reaction Time



Between-Subject Factors

Prior to participation, participants filled out short questionnaires describing their basketball experience. Participants varied in level of experience (High School Junior Varsity to College), number of years active in a basketball-related activity (6 years to 52 years), and the number of years they had been inactive at the time of their participation in the study (30 years to currently participating). The investigator grouped participants based upon their answers into two groups for each category to make comparisons for the two main dependent variables (performance and RT). Participants were first grouped into either high school (level 2) (n = 16) or college (level 3) (n = 14) experience. A 2-way mixed ANOVA (group x condition) was used to test the effects of experience on free throw performance. There was a statistically significant difference in free throw performance as a function of level of experience, $F(1, 28) = 8.07$, $p < .05$, $\eta^2 = .224$. As expected, those participants who had participated at the college level ($M = 1.75$, $SD = .031$) had a significantly higher free throw performance score than those who had only participated at the high school level ($M = 1.628$, $SD = .029$). No significant interaction was found, $F(5, 140) = 0.928$, $p > .05$, $\eta^2 = .032$.

In addition to level of basketball experience, participants were divided into two groups according to the number of years they had been active in any basketball-related activity relative to their age. Those who were active in basketball for 60% of their life or more were identified in group 1 ($n = 15$). Those who were active less than 60% of their life were identified in group 2 ($n = 14$). Data for this specific question were missing for one subject (total $n = 29$). Again, there was a statistically significant difference in free throw performance as a function of number of years active in a basketball-related activity, $F(1, 27) = 8.18$, $p < .05$, $\eta^2 = .233$. Those participants who had participated in basketball for more than 60% of their life ($M = 1.738$, $SD = .029$) had a significantly higher free throw performance score than those who had participated less during their lifetime ($M = 1.616$, $SD = .031$). No significant interaction was found, $F(5, 135) = .517$, $p > .05$, $\eta^2 = .019$.

Lastly, participants were divided into two groups according to the number of years they had been inactive from competitive basketball at the time of the study. Those who were inactive for more than one year were identified in group 1 ($n = 12$). Those who had been inactive for less than a year or were currently active in competitive basketball were identified in group 2 (n = 18). Those participants who were either currently active or were inactive for less than one year had the tendency to shoot better than those who had been inactive longer. However, there was no statistically significant difference in free throw performance as a function of number of years participants had been inactive, $F (1, 28) = 3.47$, $p > .05$, $\eta^2 = .110$. Again, no significant interaction was found, $F (5, 140) = .597$, $p > .05$, $\eta^2 = .021$.

Differences in reaction time as a function of playing experience, years active, and years inactive were also investigated. Using the same groupings as just described, no significance difference in reaction time as a function of level, $F (1, 28) = .790$, $p > .05$, $\eta^2 = .027$, years active, $F (1, 27) = 1.40$, $p > .05$, $\eta^2 = .049$, or years inactive, $F (1, 28) = .797$, $p > .05$, $\eta^2 = .028$ were found. Similarly, no significant interactions between level, $F (4, 112) = .519$, $p > .05$, $\eta^2 = .018$, years active, $F (4, 108) = 1.02$, $p > .05$, $\eta^2 = .036$, or years inactive, $F (4, 112) = 1.00$, $p > .05$, $\eta^2 = .035$ and condition were found. Previous literature did not find gender to play a role in differences in either reaction time or performance so gender in this study was not investigated.

Summary of Results

Between-subject results found that while the more experienced participants performed better across all conditions, they did not display a significantly lower reaction time. Therefore, while we can conclude that those with more basketball experience generally have better free throw performance, the free throw does not require less attention from these participants. Results showed that a secondary reaction time task had a near-linear effect on reaction time, with reaction time decreasing as the auditory tone was played closer to the end of the free throw. Because performance did not change significantly across probe positions as compared to baseline performance, we can assume that probe positions 1 and 2 require greater attentional demand, leaving less attention available to respond to the auditory tone and therefore decreasing secondary task performance. Consequently, divided attention has its most negative effect on performance during the pre-shot routine and the first upward motion of the free throw.

CHAPTER V

DISCUSSION

The division of attention to multiple sources of information has been studied in the field of psychology for many years. As researchers made the connection between task difficulty, attentional demand, and task performance, the topic gained interest of those concerned with sport. Researchers began to map out the time course of attentional demands in athletic skills ranging from horseshoe pitching to sprinting, finding that information processing is not continuous. Rather, particular points of a movement require a greater demand for attention than others (Castiello & Umilta, 1988; Prezuhy & Etnier, 2001; Sibley & Etnier, 2004). Consequently, it is not critical that attention goes uninterrupted, but that we allocate the necessary resources to the primary task when demands for those resources are essential to successful performance. When we relate this information to literature concerned with automatic and controlled processing (Beilock, McCoy, & Carr, 2004; Perkins-Ceccato, Passmore, & Lee, 2003), we see that for some tasks, such as golf putting, difficulty (and therefore attentional demand) varies as a result of expertise. The current study was not only able to identify the points of peak attentional demand in the basketball free throw, but also compared performance and reaction time as a function of expertise.

Performance

First of all, performance was not significantly different from baseline performance at any of the four probe positions or catch trials. As described earlier, in using the reaction time probe technique, attentional demand of the primary task cannot be properly assessed if the primary task is not given the most attentional weight (Prezuhy & Etnier, 2001). Given this finding, attentional demand of the primary task can be accurately assessed and changes in reaction time can be attributed to changes in attentional demand.

Reaction Time

Kahneman's (1973) theory describes attention as a limited resource that can be flexibly allocated from moment to moment. When two tasks are combined, resources must be allocated between both tasks. When tasks become more difficult, more attention is needed, increasing the amount of interference on secondary task performance (Styles, 2006). In a dual-task setup, performance on the secondary task is assessed and used to derive the attentional demand of the primary task. A primary task requiring increased attentional demand will take up more central processing space, causing decreased performance on the secondary task (Sibley & Etnier, 2004). The present study was set up to examine the time course of attentional demands by examining performance on a secondary, reaction time task. Contrary to the hypothesis, results showed that reaction time at PP1 and PP2 were significantly higher than baseline reaction time measurements. In addition, reaction time at PP1 was significantly higher than PP2, and reaction time at

PP2 was significantly higher than PP3. Therefore, according to the dual-task paradigm, we can conclude that the pre-shot routine and the first upward motion of the ball require the greatest attentional demand in the free throw process.

Because these findings are contrary to the hypothesis of the investigator, we must look at how PP1 and PP2 differ from the rest of the conditions. In basketball, the pre-shot routine is commonly used to help focus attention, reduce anxiety, eliminate distractions, and prepare for a successful free throw (Czech, Ploszay, & Burke, 2004). Many athletes are able to reach an ideal performance state by concentration on specific routines prior to the free throw. Some also suggest that the pre-shot routine allows the athlete to activate the appropriate physiological and mental state before each shot (Czech, Ploszay, & Burke, 2004). After taking a closer look at the pre-shot routine we can understand the importance of undivided attention and the role of concentration in the free throw. This study shows that the pre-shot routine is not performed automatically as originally thought. Despite how rehearsed, repetitive, and unvarying a pre-shot routine is, we see that it is important to assign this task the most attentional weight and help athletes implement focusing strategies at this time.

As stated in the results, we also see significantly higher reaction times at PP2 than baseline. This could be explained in a couple ways. First, the concentration required to initiate the free throw could be a continuation from the high level of attention needed during the pre-shot routine. Therefore, attention is highest at the time before the shot actually takes place, then decreases linearly starting at the first upward motion of the ball. Figure 6 provides an illustration for this explanation. On the other hand, the attention required to initiate the free throw may not be a continuation of attention at all. Probe positions 3 and 4 did not require any more attention than was required at baseline trials, or single-task performance (reaction time task only). These findings may suggest that even though probe positions 3 and 4 may be carried out "automatically," and do not demand a substantial amount of attention, a significant amount of attention is needed to initiate the shot. This may indicate that the free throw is part of a generalized motor program that relies on a motor plan for initiation, but once activated, is carried out with minimal use of additional neural input or kinesthetic feedback. However, further research investigating the mechanics of the free throw is needed before making such conclusions and generalizations.

The Effect of Varying Levels of Expertise

Because we did not see that reaction times significantly changed as a function of expertise, we cannot conclude that the free throw task required more attention from high school-level participants than from college-level participants. This study showed that the different components of the free throw require similar levels of attention across participants of varying basketball experience. These free throw results differ from Beilock, Carr, MacMahon, and Starkes' (2002) soccer dribbling task or Perkins-Cecato, Passmore, and Lee's (2003) golf putting task, which found that similar tasks required more attention for novice than expert athletes. Furthermore, results did not find that the number of years inactive impacted participants' reaction time differently, suggesting that once learned, athletes store the information needed to execute the free throw so it can be recalled when needed without a need for increased attentional demand. This is consistent with the earlier suggestion that the free throw is carried out by a generalized motor program that once learned, is stored in memory and available to be recalled and put into action when called upon. Again, further research and evidence is needed to validate this explanation.

Ericsson's work with the development of expertise has found that approximately 10,000 hours of deliberate practice is needed to develop expertise (Ericsson et al, 1993). More generally, the accumulated amount of deliberate practice is closely related to the attained level of performance of experts. There was no way to determine hours of deliberate practice for individuals in the current sample. Instead, expert/non-expert status was approximated by classifying available measures (college/high school level, respectively). By theoretically dividing participants into groups of "experts" and "non-experts," it was found that performance was significantly better in those participants who had generally accumulated a greater amount of basketball-related experience. However, future studies using participants of similar experience but with clearly different hours of deliberate practice would make these conclusions more valid. While we would predict a similar effect of experience on performance, we might see differences in reaction time in those with little basketball experience. The task may be more difficult for those with less than high school experience, therefore requiring more attention. Future studies comparing novice athletes instead of athletes with high school playing experience may show results similar to that of Beilock, Carr, MacMahon, and Starkes (2002) and Perkins-Ceccato, Passmore, and Lee (2003), where the unfamiliarity of the task disrupts skill execution, demanding an increased level of attention to be devoted to the free throw, and compromising secondary reaction time performance.

Limitations and Future Directions

A study with greater ranges of basketball experience and free throw ability would give us more information as to how these factors impact the dependent variables. For this study's purposes, the subject pool was sufficient to give us information on the time course of attention for the basketball free throw. However, true novice athletes were not used in this study, as all participants had at least two years of high school basketball experience. Perhaps using participants with minimal basketball experience, we would see results that are similar to Beilock, Carr, MacMahon, and Starkes' (2002) and Perkins-Cecato, Passmore, and Lee's (2003) findings on the use of automatic and controlled processing in expert versus novice athletes. Future studies designed to test the effect of specific factors on free throw performance and secondary reaction time performance would give us additional insight into the time course of attentional demands in the basketball free throw.

Conclusions

Everyday we encounter evidence of our limits in attention. From William James' original definition to today's research on sport performance, the study of attention has progressed and has suggested some valuable conclusions about performance costs of dividing attention. A review of literature in sport and dual-task performance provides evidence for Kahneman's (1973) two predictions. First, by using the reaction time probe technique, we find that interference occurs even when the two activities do not share any mechanisms. For example, listening for an auditory tone and performing a motor task such as a free throw still produces interference that negatively affects performance even though the two tasks do not share a similar mechanism. Secondly, we have evidence that the extent of interference will depend in part on the attentional load that each of the activities imposes. Multiple studies have found relationships between the magnitude of attentional load and secondary task performance. While some motor tasks require an increased attentional demand near the beginning and end of the task (Sibley & Etnier, 2004; Prezuhy & Etnier, 2001; Castiello & Umilta, 1988), others show a linear relationship, with either peak attentional demand at the beginning of the task, such as the present study, or near the end of the task (Rose & Christina, 1990).

Implications for practitioners, coaches, and athletes are the most important aspects of these findings. Mapping the time course of attention for a particular skill gives us a model from which focusing strategies can be developed. For example, in the present study, focusing strategies that are individualized to meet personal preferences should be utilized during the pre-shot routine and the first upward motion of the ball. If athletes are able to use techniques to focus attention to the pre-shot routine and free throw technique, distractions from the crowd, the opposing team, or negative self-talk should not divide attention and ultimately hurt performance. Performance data have shown that it is possible to maintain performance (compared to baseline performance scores) under dual-task conditions. However, performance must be kept as the primary goal and assigned the most attentional weight.

If we revisit Yogi Berra's question "How can you hit and think at the same time?" we see that attention is not necessarily continuous, but is needed in increasing and decreasing amounts over the duration of a specific task. While we do not completely understand how automatic and controlled processing works, results suggest that because attention is not continuous, some parts of a task are carried out automatically and do not draw on attentional capacity. However, we do know that a lack of attention to particular parts of skill execution may be associated with less successful performance, even for individuals with many years experience.

The results of this study are both similar and different from past literature on dual-task performance in sport. The dual-task paradigm and reaction time probe technique was successful in identifying the times of peak attentional demand in the basketball free throw. In addition, because performance did not significantly change over the different conditions, we can assume that results are due to the increase in attentional resources needed to shoot free throws and not because participants reprioritized the primary and secondary task. However, the free throw did produce results that were different than other skills in different sports. This suggests that attentional demands are unique to individual skills and we should consider the task before applying focusing strategies for performance enhancement.

Overall, the vast difference in free throw accuracy among individuals playing at elite levels of basketball may be due to skills beyond those attributed to physical ability. Thus, establishing mental skills and training the mind along with the body are of particular importance. As basketball evolves into a dynamic game of quickness and decision-making, the free throw will always be a skill dominated by those who can control both physical and mental skills. Although we have insight into the impact of attentional disruption on performance, future studies may provide further evidence as to how the mind manages multiple forms of incoming information and how athletes assign attentional resources to varying task demands.

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APPENDIX A: INFORMED CONSENT

Informed Consent

Project Title: **Accuracy of Free Throw Shooting During Dual-Task Performance: Implications of Attentional Disruption on Performance.**

Project Director: **Jayme Price, MS student – University of North Carolina at Greensboro**

Participant's Name:

Before agreeing to participate in this research study, it is important that you read the following explanation of this study. This statement describes the purpose, procedures, benefits, risks, discomforts, and precautions of the experiment. Also described is your right to withdraw from the study at any time. No guarantees or assurances can be made as to the result of the study.

Description and Explanation of Procedures
This is a research study to examine the attentional demands of the basketball free throw. The goal of the study is to generate an understanding of how the processing of multiple forms of information simultaneously may affect performance. People choosing to participate in this study must be at least 18 years of age and have a minimum of 2 years high school basketball experience. Participants will be asked to shoot 50 free throws. Free throw performance will be scored based upon accuracy. On random trials an auditory tone will be administered. On these trials participants will be asked to respond as quickly as possible to the tone by saying "ball." A special microphone that will be clipped to the participant's shirt will pick up both the auditory tone and verbal response. Reaction time, defined by the amount of time between the presentation of the sound and the verbal response, will be recorded by a specialized computer software program. Procedures of this study will also be videotaped to ensure accurate measurement. It is critical that the participant treat the free throw as the primary task, assigning it the most attentional weight. Therefore, it is the participant's goal to do as well as possible on the primary task and, given that constraint, as well as possible on the secondary reaction time task. The length of participation should be approximately 30 minutes.

Risks and Discomforts
There is minimal risk from the procedures of this experiment. However, participants may experience muscle soreness related to free throw shooting.

Potential Benefits

There are no immediate benefits to the individual participating in this study. However, the results of the study may contribute to the understanding of how athletes distribute attentional resources during the basketball free throw. Identifying the time of peak attentional demand has important implications for basketball players and coaches who want to understand the effects of distractions on performance. The results may provide coaches and athletes with information that can be used to improve free throw performance.

Confidentiality

All information gathered from the study will remain confidential. The results of the study may be published for scientific purposes in the future. All participants will be assigned an identification number, therefore, participant identity will not be revealed. Only the researcher will have access to the study data and information. All study results and information will be kept in a private file in the locked office of the investigator and then destroyed via paper shredder by the investigator 3 years after the project is complete. All video-recorded data will be erased.

Compensation/Treatment For Injury

The University of North Carolina at Greensboro has made no provision for monetary compensation in the event of injury resulting from the research. This study poses minimal risk. However, in the unlikely event of injury the investigator will provide assistance in locating and accessing appropriate health care services. The cost of such health care services is the responsibility of the participant.

Consent

By signing this consent form, you agree that you understand the procedures and any risks and benefits involved in this research. You are free to refuse to participate or to withdraw your consent to participate in this research at any time without penalty or prejudice; your participation is entirely voluntary. Your privacy will be protected because you will not be identified by name as a participant in this project.

The University of North Carolina at Greensboro Institutional Review Board, which ensures that research involving people follows federal regulations, has approved the research and this consent form. Questions regarding your rights as a participant in this project can be answered by calling Mr. Eric Allen at (336) 256-1482. If you have any questions directly related to the study, its purpose, or are interested in the results of the experiments contact Jayme Price at 419-348-8729 or JLPRICE5@uncg.edu. Any new information that develops during the project will be provided to you if the information might affect your willingness to continue participation in the project.

By signing this form, you are indicating that you are 18 years of age or older, and agreeing to participate in the project described to you by Jayme Price.

________________________________ ____________________

Signature of Subject Date

____

Subject name (printed)

APPENDIX B: PARTICIPANT QUESTIONNAIRE

Participant Questionnaire

In order for us to collect background data that is critical to the study, you are asked to fill out the following questionnaire in its entirety. Please complete the measure and answer all items on your basketball experience**.**

Number of years of High School basketball experience: ________________________

Please circle the highest level of basketball experience you were once active in (circle one):

JV **Varsity** **College**

Indicate the number of years you have been active in any basketball-related activity: _______

Indicate how long it has been since you've last played basketball competitively (if you are currently active write "current"): _____________