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Time Estimation Among Basketball Players

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TIME ESTIMATION AMONG BASKETBALL PLAYERS

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In loving memory of my grandmother, Shirley Irene Waldron,

whose pursuit of education has been my inspiration.

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ABSTRACT

Extensive research has provided much evidence for an attention-based model of time estimation (Zakay, 1992; Zakay, 1993a; Zakay 1993b; Zakay, 1998; Zakay, Nitzan, & Glicksohn, 1983; Zakay & Tsal, 1989); however, limited research on time estimation has been conducted in the sport domain. The purpose of this study was to extend time estimation research and the notion of an attention-based model into the sport arena, specifically basketball. This study implemented principles of the automatization theory (Brown, 1997) to a situation where the task is automatically performed without the need of directed attention. In particular, this study added a familiar time interval, 30 seconds, which was considered familiar to basketball players because they are accustomed to estimating it through the 30 second shot clock. Twenty female individuals within the age range of 12 – 22 participated in the study (i.e., ten basketball players and ten non-basketball players). The participants estimated three different time intervals: the familiar time interval (i.e., 30 s), a shorter time than the familiar interval (i.e., 20 s), and a longer time interval (i.e., 40 s). All estimations were done through a reproduction method. Three types of non-temporal tasks were utilized as interference with the timing task (i.e., cognitive, motor, and visual). Each interference task consisted of two difficulty levels, easy and hard. The cognitive task involved counting backwards by five (i.e., easy) or by three (i.e., hard). Dribbling one basketball was the easy motor task, while simultaneously dribbling three basketballs was the hard motor task. For the visual task participants searched for a target letter, 'K', among circular distracters, C, O, Q, U (i.e., easy) or angular distracters, V, W, X, and Y (i.e., hard). The participants first engaged in a single task, either reproducing the time intervals or performing the non-temporal tasks for all three time interval durations. Each condition consisted of four trials. A week later all participants engaged in the dual tasks, estimating the time intervals while performing the distracter non-temporal tasks. Findings revealed that basketball players experienced less interference from the non-temporal distracter tasks than non-basketball players. Basketball players were more accurate on their time estimations on all three time intervals across all types of interference than non-basketball players. Their closest estimations were during the 20 s time interval. Previous research on time estimation in sport has been extremely limited. This study provides further support for an attention-based model of time estimation, specifically within sport. The findings also suggest that athletes engaged in sport which require time estimation develop a better “sense for time” than people who have not been familiar with time constraints. Interestingly, time estimation of athletes is better than non-athletes not particularly in the specific sport time, but rather along all time estimations alike.

CHAPTER 1

INTRODUCTION

Sports are laden with time constraints. Basketball involves various time limitations including thirty seconds to get a shot off, three seconds in the lane, and five seconds to in bound the ball. Despite the importance of a time variable in various sports, limited research has been conducted in the area of time estimation among athletes. One early study by Andrew Hepworth (1968) explored time estimation among track athletes. Although a small sample size was used, Hepworth found that track athletes were better able to produce specified time intervals than non-athletes.

While there is a lack of time estimation research in sport, extensive research has been conducted on time estimation outside the sport arena. Zakay and colleagues have provided much evidence to support an attention-based model of time estimation (Zakay, 1992; Zakay, 1993a; Zakay 1993b; Zakay, 1998; Zakay, Nitzan, & Glicksohn, 1983; Zakay & Tsal, 1989). According to attentional model theorists time estimation accuracy is directly related to the amount of attention that is allocated for processing the passage of time (Zakay, 1992). Attempts to validate this attentional model involve manipulating situations in which participants allocate more or less attention to timing than to a concurrent non-temporal task.

One aspect studied in time estimation is automaticity, which "refers to performing a highly practiced task with few or no processing resources" (Brown, 1997, p.1125). Brown and Bennett (2002) found that practice on a non-temporal task resulted in less interference in timing from this concurrent non-temporal distracter task. They indicated that practice on the task leads to a shift in cognitive processing such that the task uses fewer additional resources as different parts of the performance becomes automatized.

In this study it is theorized that automatization can be applied to the situation in which the timing task becomes more automatic, and thus results in less interference from non-temporal distracter tasks. Specifically it is hypothesized that basketball players who regularly engage in estimation of 30 seconds (through estimation of 30 seconds on the shot clock) will be more accurate in their time estimations, and will be less influenced by non-temporal distracter tasks as compared to non-basketball players. This is the main purpose of the current study.

CHAPTER 2

LITERATURE REVIEW

Time estimation is a complex cognitive process that is influenced by various factors. Hicks, Miller and Kinsbourne (1976) identified the following four factors that influence the process of time estimation: (a) method of time estimation (e.g., absolute time judgment by production, verbal estimation or reproduction, or comparative time judgment); (b) duration of the interval to be estimated; (c) the nature of processing required of the subject during the interval to be estimated (e.g., empty or filled interval); and (d) the nature of the measurement paradigm (e.g., a prospective paradigm in which the subject knows in advance that he or she will be required to estimate the elapsed time, or a retrospective paradigm in which the subject is told the nature of the task only after the target interval is over).

Another model that defines the pertinent factors of time estimation is Block's (1989) contextual model of temporal experience. This framework is considered, "contextualistic because it emphasizes factors surrounding an event or episode, which influence an organism's encoding of, conceiving of, and responding to the event or episode" (Block, 1989, p.28). Block outlined four factors influencing perceived time: (a) characteristics of the time experiencer (e.g., sex, personality, interests, temporal perspective, and previous experiences); (b) contents of a time period (e.g., number, complexity, modality and duration of events); (c) activities during a time period (e.g., ranges from passive non-attending to strategies used to acquire information); and (d) time-related behaviors and judgments (e.g., simultaneity, rhythm, order, spacing, duration, etc.).

Time estimation models

Ornstein (1969) proposed a storage-size model to account for time estimation experiences. He stated that the estimated duration of an interval at a given moment is proportional to the storage size in memory taken up by encoded and later retrievable stimulus information. Ornstein claimed that when a person encodes large amounts of stimuli during a time period, or if the stimuli are encoded in a complex way, the estimation of the time period lengthens. Although Ornstein's storage-size model has received some recognition, alternative attentional models (Zakay et al., 1983) have benefited from greater empirical support. According to attentional theorists Frankenhauser (1959) and Priestly (1968) time estimation is a direct function of the amount of attention that is allocated to the passage of time.

Thomas and Weaver (1975) developed and tested a mathematical model addressing attentional allocation effects on perceived time duration. The model is in the form of a functional equation:

$$\tau(I) = af(t,I) + (1-a)\, g^*(I) \qquad (1)$$

where perceived time duration (τ) of a time interval containing certain information (I) is dependent upon the weighted average of the amount of information encoded by two processors, [f(t,I)] and [g*(I)]. Attention is divided between these two processors of which the first [f(t,I)] is a temporal information processor, or a timer, and the second [g*(I)] is a non-temporal information processor. In order to optimize the reliability of the information that each processor encodes, the perceived duration is weighted with probability parameter *a*. As more attention is allocated to one processor the other becomes less influential. As *a* approaches 0, the subject encodes more non-temporal information and as *a* approaches 1, the subject encodes more temporal information. According to this model, perceived time duration increases with processing load.

Zakay, Nitzan, and Glicksohn (1983) suggested the following elaboration of Thomas and Weaver's (1975) model:

$$\text{Time estimation} = f\{\gamma[P(t)];\, \beta[P(I)]\}\ ;\ \gamma + \beta = 1, \qquad (2)$$

where γ and β are "importance" weights attached to information obtained from the two processors, ([P(t)] - temporal information processor, and [P(I)] – non-temporal information processor) after the information processing has been terminated. The “importance” weights are influenced by attentional demands, as well as other factors, such as the estimation paradigm (e.g., absolute or comparative) and the interval duration. It is reasonable to assume γ is very small for very short durations, because the timer is not very effective, and γ becomes larger when the time interval duration is longer (Zakay et al., 1983).

Zakay and Block (1996) proposed an attentional-gate model that takes into consideration both automatic and controlled attentional influences on prospective duration estimation. The model consists of a pacemaker, a gate, a switch, and a cognitive counter (see Figure 1).

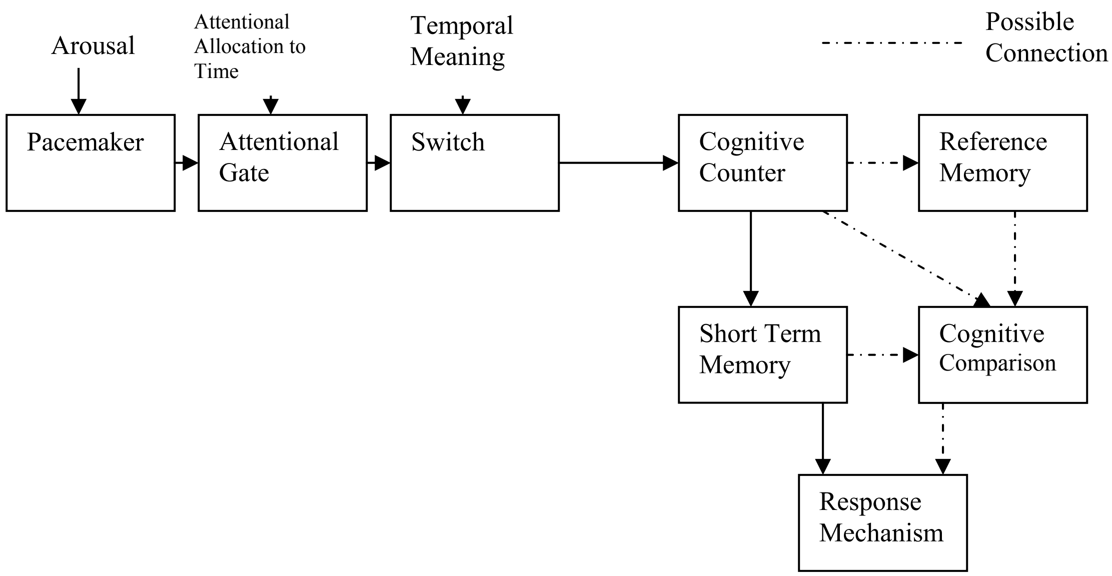

Figure 1. The Attentional-Gate Model (Zakay and Block, 1996, p.154. The role of attention in time estimation processes. In M.A. Pastor & J. Artieda (Eds.), *Time, internal clocks and movement* (pp. 143-164). Amsterdam: Elsevier.)

The pacemaker produces pulses at a rate influenced by general arousal, and specific stimulus-induced arousal. When a person is attending to time, and not to external stimuli, the attentional gate opens more frequently. This allows more
pulses to be transferred from the pacemaker to the cognitive counter. When time is not relevant, the gate narrows, allowing fewer pulses to pass through. According to this model time estimation judgments involve counting the total pulses in the cognitive counter. This model also includes a switch that opens or closes the pathway to the

counter. This switch is either completely open or fully closed depending on the temporal meaning of the stimuli. When a person perceives stimuli that indicate the beginning of a relevant interval, the switch opens, the counter starts at zero and pulses begin to accumulate. The pathway is closed by the switch when stimuli are perceived, which indicates the end of the relevant interval. The counted number of pulses is transferred to short term memory when an estimation or response is needed.

Although memory-based and attentional models have both gained empirical support, they produced contradictory results (Zakay, 1989). A duration estimate based on a cognitive timer produces a negative relationship between the subjective time duration and the information load (Zakay, 1989). According to attentional models, the increase in the information load produces a shortening of the perceived duration. However, an estimate based on storage sized models increases in length as the information load intensifies, creating a positive relationship (Zakay, 1989). Zakay proposed an elaboration of Thomas and Weaver's model to explain this incongruence. He suggested that only the output of the most reliable processor is used to judge the duration of the interval. Therefore, Zakay theorized that memory based models apply when P(I) (non-temporal information processor) dominates the estimation process because it is linearly and positively correlated with the information processing load; attentional models apply when P(t) (temporal information processor) dominates, because it is linearly and negatively correlated with the information processing load.

Methods of time estimation

Two common methods in time estimation, prospective and retrospective judgments of time intervals are used in most studies. When the subject is aware of the timing task before the interval starts, a prospective method is employed. A retrospective judgment occurs when the subject has no prior knowledge that he/she will be asked to estimate the interval. There is some discrepancy in whether or not different cognitive processes govern each type of temporal judgment (i.e., retrospective and prospective); however, it is generally accepted that attentional processes play a significant part in prospective timing (Zakay, 1998). Therefore, prospective judgments have been chosen for this particular study.

Zakay (1989, Experiment 1) introduced a new factor into time estimation paradigms; specifically, the estimation delay or the amount of time that lapses between the termination of the interval, and its actual estimation. Immediate Estimation (IE) is defined as an estimation that was performed immediately upon the end of the target interval. Remote estimation (RE) is an estimation performed after a given period of time has passed after the end of the interval. Zakay found under prospective conditions a negative trend i.e. the estimated time interval shortened as the task difficulty increased (supporting attentional based processes), for immediate estimation; estimated time interval lengthened as the task difficulty increased (supporting storage size based processes) for remote estimation. Immediate estimation supports attentional based processes and therefore will be utilized in the current study.

Research findings

The "interference effect" is a consistent finding in time perception literature that refers to a disruption in timing, which occurs when a subject is required to perform a non-temporal task during the estimated time interval (Brown, 1997). Perceived time of an interval becomes shortened when a disruption is present (Brown, 1997). This result is manifested differently according to the methodology of the experiment. With verbal estimations and reproductions subjects are given an interval and subsequently asked to determine its length. As a result of distraction fewer temporal cues are perceived than are usually attended to, and consequently time estimations are shortened. Conversely, the production method requires the subject to generate a specified interval. If the conditions distract the subject, some temporal cues may be missed, causing the subject to allow more time to pass before he/she judges that the interval has expired.

Various non-temporal distracter tasks have been introduced in time estimation studies. These tasks explore a wide range of processes including perceptual-motor coordination, cognitive processes, and visual/spatial processing. Tasks requiring perceptual-motor coordination included mechanical problem solving (Hawkins & Meyer, 1965), weight discrimination (Harton, 1938b), reversed printing (DeWolfe & Duncan, 1959), and mirror drawing (Brown, 1985, Experiment 1; Wilsoncroft & Stone, 1975). These perceptual-motor coordination tasks performed concurrently with a timing task have been shown to shorten the perceived time in relation to non-task conditions.

Several cognitive tasks have also consistently shown a disruption in timing. One such task involves response uncertainty, and is often attained through card sorting. A participant is instructed to sort the cards into a single stack, which involves 0 bits of information, two stacks according to color, engaging 1 bit of information, or four stacks based on suit involving 2 bits of information. An inverse relationship was noted between the response uncertainty (0, 1 and 2 bits) and the magnitude of time estimates. As more bits of information were required, the intervals were judged to be shorter (Allen, 1980; Zakay, 1992, Experiment 1). Other cognitive tasks involve mental arithmetic. Numerous studies entailing addition and multiplication have indicated a shortening of the estimated time durations as compared to control conditions (Burnside, 1971; Wilsoncroft & Stone, 1975). Hawkes and Sherman (1972) used the addition of three digits to a second set of three digits, and subsequently subtracting a third set as interference with the timing task. Results indicated that this task shortened perceived time. Gulliksen (1927) had previously shown that long division created a similar effect by shortening the perceived length of the intervals. Marmaras, Vassilakis, and Dounias (1995) used math tasks and concluded that accuracy of time estimation decreased as the cognitive demands of the concurrent task increased.

Demanding attentional tasks create inaccuracy and a shortening of the estimated time interval (Brown, 1985 Experiment 2; Tsao, Wittlieb, Miller & Wang 1983). Brown's demanding attentional task involved listening to a word list presented to the right ear, and ignoring a word list presented in the left ear (selected attention) versus attending simultaneously to the right and left ear word lists (divided attention). Prospective judgments became shorter and more inaccurate with the presence of non-temporal task demands. Tsao, Wittlieb, Miller and Wang (1983) instructed participants to estimate the duration of a tone played in their ear while repeating a recorded passage aloud. A shortening of estimated time intervals were observed as the shadowing task became more difficult.

In several studies task difficulty varied in a non-temporal task. Results have consistently shown shortening of perceived time as the task's difficulty increases (Harton, 1938a; Smith, 1969; Zakay et. al., 1983). However, Wilsoncroft, Stone and Bagrash (1978) failed to replicate this finding using mental multiplication problems; easy and hard differentiations were determined by the size of the digits, i.e., small (2-5) digits were considered easy and large (6-9) digits were hard.

Equivocal results were reported in studies manipulating the depth of processing to reliably interfere with timing estimation. The task required the subjects to respond to the structural features of words (shallow processing) or the semantic aspects (deep processing). McClain (1983) instructed participants to either classify words as starting with the letters A-L or M-Z (shallow processing) or classify the words as living or non-living (deep processing). McClain suggested that deeper processing was linked with shorter and more inaccurate judgments. However, Block (1992) failed to obtain interference of the manipulation with prospective timing, and Martinez (1994) found ambiguous patterns.

A number of studies have explored timing along with other cognitive tasks, such as memory tasks (Hicks & Brundige, 1974), proofreading (Brown & Stubbs, 1992), verbal rehearsal (Miller, Hicks & Willette, 1978) and anagram solving (DeWolfe & Duncan, 1959). Consistent findings indicated a shortening of perceived time (Brown & Stubbs, 1992; DeWolfe & Duncan, 1959; Miller, Hicks & Willette, 1978). For example, Hicks and Brundige found perceived time to be 68% of the actual time with a concurrent memory task.

A few studies utilized non-temporal distracter tasks involving visual or spatial processing. Maze learning (Cohen, 1971; Harton, 1939; Harton, 1942), mirror reading (Gulliksen, 1927), and mental rotation (Fortin & Brenton, 1995, Experiment 3) have been found to shorten perceived time. Visual search tasks, which require subjects to scan distracter stimuli in order to locate a target stimulus (or its absence), resulted in a shortening in perceived time (Fortin, Rousseau, Bourque, & Kirouac, 1993, Experiment 2).

Numerous non-temporal distracter tasks have been shown to interfere with a concurrent timing task. An area of time estimation research that has yet to be explored is the effect of a non-temporal distracter task on the accuracy of estimating a familiar time interval. This study attempts to extend the knowledge of time estimation research by introducing the estimation of a familiar time interval. Along the lines of familiarity, Brown and Bennett (2002) studied the effect of practice on a non-temporal task. Practice on the task led to a shift in cognitive processing such that the non-temporal task used fewer additional resources as different parts of the performance became automatized. This automatization resulted in less interference with the timing task. The current study theorizes that this automatization can be applied to the situation in which the timing task becomes more automatic, and thus results in less interference from non-temporal distracter tasks. Specifically, that basketball players who regularly engage in estimation of 30 s (through estimation of 30 s on the shot clock) will be more accurate in their time estimations, and will be less influenced by non-temporal distracter tasks than non-basketball players.

The non-temporal distracter tasks utilized in this study include motor, cognitive and visual search tasks. Studies have shown shortening of perceived time as the task's difficulty increases (Harton, 1938a; Smith, 1969; Zakay et. al., 1983); consequently, each task in the current study involves two levels of difficulty, easy and hard. The motor task consists of dribbling one basketball (easy) and dribbling three basketballs simultaneously (hard). The easy motor task is assumed to produce the least amount of interference with the timing task as basketball players are continually engaging in motor tasks. The hard motor task is assumed to create more interference than the easy motor task. Various studies have shown mental arithmetic to interfere with timing (Burnside, 1971; Gulliksen, 1927; Hawkes & Sherman, 1972; Marmaras et al., 1995; Wilsoncroft & Stone, 1975); accordingly, subtraction has been chosen as the cognitive task (i.e., subtracting by 5 is the easy task and subtracting by 3 is the hard task). This task is thought to produce the strongest amount of interference with the concurrent timing task as basketball players do not regularly engage in this type of cognitive task. The third task involves visual search which has been shown to interfere with the estimation of a time interval (Fortin et al., 1993, Experiment 2). This task has been modeled after the visual search task utilized by Brown (1997, Experiment 2). For the easy visual task subjects will be asked to locate the letter 'K' among round distracters, C, O, Q, U. The difficult visual task will involve locating the letter 'K' among angular distracters, V, W, X, Y. The mean probability for confusing the target letter 'K' with the round distracters is .004, while the equivalent value for the angular distracters is .083 (van der Heijden, Malhas, & van den Roovaart, 1984).

Transfer

Transfer is the gain or loss in the capability for performance in one task as a result of practice or experience on some other task (Schmidt & Lee, 1999). The effectiveness of transfer relies on Thorndike and Woodworth's (1901) theory of "identical elements," stating that the determinant of transfer is the extent to which the two tasks contain identical elements. Tasks with more shared elements are more similar, and therefore result in better transfer. When transfer does occur it is often small and positive, unless the tasks are practically identical (Barnett & Ceci, 2002; Schmidt & Lee, 1999). Thus, in the present study, it is hypothesized that time estimation ability inherent in the basketball competition task will transfer to the experimental task. To elaborate, it is hypothesized that basketball players will reproduce the 30 s time interval more precisely then the 20 s and 40 s time intervals, because the 30 s time interval is more representative of the basketball competition task than the 20 s and 40 s time intervals. The similar, if not identical, element between a basketball competition and the experimental condition is the temporal aspect of the tasks; both tasks require an awareness by the individual of 30 s in time. Although the conditions (i.e., a basketball competition and this study) involve different forms of non-temporal interference, it is theorized that all interferences require a similar type of attention. Thus they are utilizing various extents of the same attention, and should produce comparable effects on time estimation accuracy.

Purpose of the study

Although time estimation research is extensive it is scarce in the sport domain. Automaticity has been explored in time estimation research; however, the focus has been on the automaticity of the non-temporal distracter task. This study intends to investigate the potential automaticity of the timing task through estimations of a familiar time interval. The purpose of this study is to extend time estimation research into the sport domain, specifically basketball, as well as to introduce estimation of a familiar time interval.

Hypotheses

1) Overall, basketball players will estimate the 30 s time interval more accurately than non-basketball players under:
    a) non-interference condition

    b) motor interference, easy and hard

2) All participants will be more inaccurate in time estimation under the hard than under the simple interferences (cognitive, motor, visual).
3) Time estimation of basketball players will be more accurate than non-basketball players for 30 s during the motor interference than for the cognitive and visual interference, under both easy and hard interference (cognitive, motor, visual). Estimations during the 30 s will be more accurate than the 20 s and 40 s conditions.

CHAPTER 3

METHOD

Participants

Ten female basketball players from an US northeastern community were asked to voluntarily participate in the study. All ten participated in the study. The average age of the basketball players was 16.9 (SD = 3.07). The basketball players had a mean of 6.3 years of basketball experience (range = 2-10 years). An age and gender matched sample of ten non-basketball players was also employed. The average age of the non-basketball players was 15.7 (SD = 1.57).

Apparatus

This study entailed three different types of non-temporal distracter tasks – motor, cognitive, and visual search over three different time intervals. The time intervals included a familiar time interval (i.e. 30 s), a shorter time than the familiar interval (i.e., 20 s), and a longer interval (i.e. 40 s). Each task involved two difficulty levels – easy and hard. Figure 2 depicts the study's design. A stopwatch was utilized to time the intervals.

Motor interference

Regulation size basketballs were used for the motor tasks. Outside on a track, one basketball was dribbled during the easy task condition, while three basketballs were dribbled simultaneously during the hard task condition. Both of these tasks were preformed for the duration of each time interval. A stopwatch was started at the onset of the interval as the researcher instructed the participant to begin the task. The researcher verbally indicated the end of the interval (i.e., saying "stop"). The participant was then instructed to reproduce the time interval on the stopwatch by verbally indicating to the researcher when to start and stop the stopwatch.

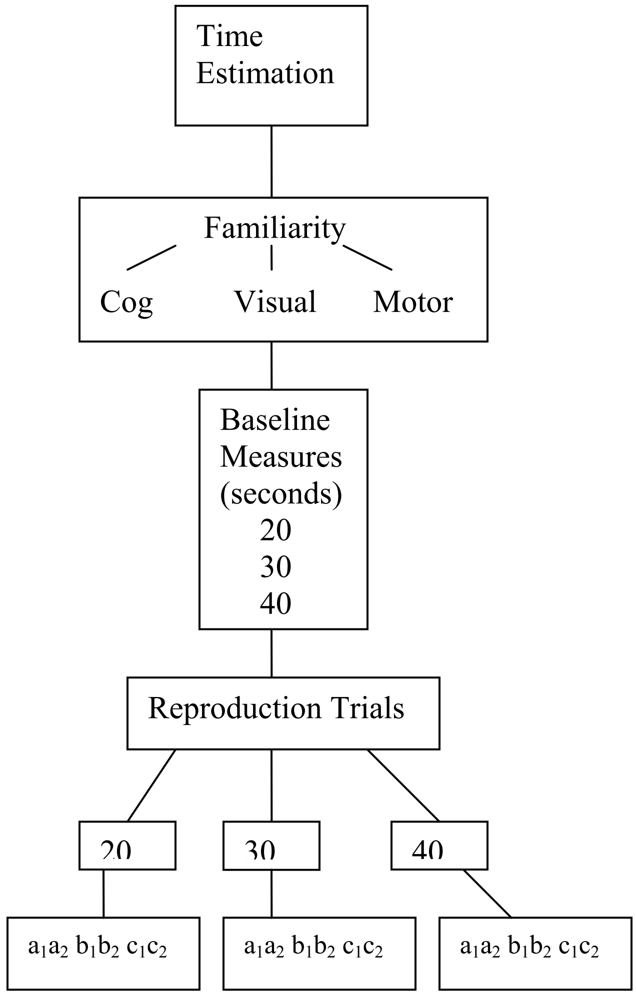

Figure 2. Conceptual Map for Study's Design

a=cognitive task, b=visual task, c=motor task; 1=easy level, 2=hard level

Cognitive interference

The participants were asked to count backwards loudly by 5 (easy task) and by 3 (hard task) in order to cognitively interfere with time estimation. The tasks were preformed for the duration of the three time intervals. A stopwatch was started at the onset of the interval as the researcher instructed the participant to begin the task. The researcher verbally indicated the end of the interval (i.e., saying "stop"). The participant was then instructed to reproduce the time interval on the stopwatch by verbally indicating to the researcher when to start and stop the stopwatch.

Visual interference

Letters were typed on sheets of paper in uppercase 12 point font for the visual search task. Each sheet contained 26 lines of letters with each line consisting of 40 letters with a space between each letter. A random number sequence number was used to determine the sequence of the letters. For the easy visual task subjects were asked to locate the letter ‘K’ among round distracters, C, O, Q, U. The hard visual task involved locating the letter ‘K’ among angular distracters, V, W, X, Y. The tasks were preformed for the duration of the three time intervals. A stopwatch was started at the onset of the interval as the researcher instructed the participant to begin the task. The researcher verbally indicated the end of the interval (i.e., saying “stop”). The participant was then instructed to reproduce the time interval on the stopwatch by verbally indicating to the researcher when to start and stop the stopwatch.

Procedure

Participants were gathered on a volunteer basis. The participants (i.e., both basketball and non-basketball players) were recruited through contact with the high school soccer coach. After a meeting with the coach, the participants were given a Parental Consent form (Appendix A). Once the Parental Consent forms were signed and returned an initial meeting was scheduled. Participants were given instruction and explanation that minimal risk is associated with the task to be performed and their rights to withdraw at any time if they so choose. Participants were asked to contribute to the study, which explores time estimation. At this time participants were asked to read and sign a players’ consent form (Appendix B).

Session 1

Participants were asked to remove all watches before testing. Table 1 outlines the task conditions of the two sessions. Session 1 includes the single-task conditions. This session required approximately one hour with each participant. The order of these single-task conditions was chosen randomly. These conditions include performance on timing through the production of three time intervals.

Table 1

Outline of Task Conditions for Sessions

Session 1: Single-task Conditions	
Time reproduction – no interference	*No time reproduction*
20 s timing	Easy motor task for 20 s
30 s timing	Hard motor task for 20 s
40 s timing	Easy motor task for 30 s
	Hard motor task for 30 s
	Easy motor task for 40 s
	Hard motor task for 40 s
	Easy visual task for 20 s
	Hard visual task for 20 s
	Easy visual task for 30 s
	Hard visual task for 30 s
	Easy visual task for 40 s
	Hard visual task for 40 s
	Easy cognitive task for 20 s
	Hard cognitive task for 20 s
	Easy cognitive task for 30 s
	Hard cognitive task for 30 s
	Easy cognitive task for 40 s
	Hard cognitive task for 40 s
Session 2: Dual-task Conditions	
20 s timing + Easy motor task	
20 s timing + Hard motor task	
30 s timing + Easy motor task	
30 s timing + Hard motor task	
40 s timing + Easy motor task	
40 s timing + Hard motor task	
20 s timing + Easy cognitive task	
20 s timing + Hard cognitive task	
30 s timing + Easy cognitive task	
30 s timing + Hard cognitive task	
40 s timing + Easy cognitive task	
40 s timing + Hard cognitive task	
20 s timing + Easy visual search task	
20 s timing + Hard visual search task	
30 s timing + Easy visual search task	
30 s timing + Hard visual search task	
40 s timing + Easy visual search task	
40 s timing + Hard visual search task	

Subjects were tested on 20 s, 30 s and 40 s intervals. Four trials (Brown, 1997) were conducted for each time interval (total of 12 trials). The length of the time interval to be estimated was picked randomly. The researcher verbally indicated the start and stop of the interval. The participant was then instructed to reproduce the time interval on the stopwatch by verbally indicating to the researcher when to start and stop the stopwatch. Participants were encouraged to refrain from counting during the time interval.

Participants were also tested on performance during the single-task conditions of the non-temporal tasks (i.e., motor, cognitive, and visual search task). The participants performed four trials (Brown, 1997) at each level of the motor task for the three time intervals. The difficulty level and the length of the time interval were chosen randomly. The researcher verbally indicated the start and stop of the time interval. This performance was measured by the total amount of time that the subject had all basketballs bouncing at once.

The participants performed four trials at each level of the cognitive task for the three time intervals. The difficulty level and the length of the time interval were selected randomly. The researcher verbally indicated the start and stop of the time interval. The cognitive tasks required the participants to count backwards loudly by 5 (easy task) or 3 (hard task). The starting number was chosen from a random numbers table, with the requirements that it falls between 100 and 999 for both levels of difficulty and ends with either a five or a zero for the easy task condition. The subject's performance was recorded in regard to how many times the participant subtracted by the factor and by the number of mistakes (wrong answers).

Participants were asked to perform the visual search task. For the easy visual task subjects were asked to locate the letter 'K' among round distracters, C, O, Q, U. The difficult visual task involved locating the letter 'K' among angular distracters, V, W, X, Y. The participants were instructed to scan across each line of letters from left and right and to mark each target they find. The participants were instructed to circle the last letter they examined when the trial ends. This task involved four trials on each time interval for the easy and hard level task. The difficulty level and the length of the time interval were chosen randomly. The researcher verbally indicated the start and stop of the time interval. This performance was based on how many target letters ('K') the participant marked, how many target letters ('K') were missed, how many distracter letters were marked and how many total letters the participant scanned.

Session 2

The researcher returned in approximately one week to conduct Session 2 with the dual task conditions. Session 2 involved approximately 1 hour and 30 minutes with each participant. The dual task conditions consisted of the motor and timing task, the cognitive and timing task, and the visual and timing task. The order of these conditions was chosen randomly. For the motor and timing task, participants were asked to engage in the motor task for a specified time interval. The difficulty level and the length of the time interval were chosen randomly. When the researcher verbally announced the start of the interval, the participant engaged in the non-temporal distracter task until the researcher said "stop", indicating the end of the interval. The participant was then instructed to reproduce the time interval on the stopwatch by verbally indicating to the researcher when to start and stop the stopwatch. Four trials of each condition were employed. The performance was measured by the total amount of time that the subject had all basketballs bouncing at once. The participant's estimation of the time interval was also recorded. After the participant performed the dual-task conditions a manipulation check questionnaire was administered (Appendix C). This questionnaire is designed to validate that the non-temporal tasks provided interference with the time estimation task.

For the cognitive and timing task, participants were asked to engage in the cognitive task for a specified time interval. The difficulty level and the length of the time interval were chosen randomly. Four trials of each condition were used. When the researcher verbally announced the start of the interval, the participant engaged in the cognitive task until the researcher said "stop", indicating the end of the interval. The participant was then instructed to reproduce the time interval on the stopwatch by verbally indicating to the researcher when to start and stop the stopwatch. The performance was recorded in regard to how many times the participant subtracted by the factor and by the number of mistakes (wrong answers).The participant's estimation of the time interval was also recorded. Afterwards the participant was asked to fill out the manipulation check questionnaire (Appendix C).

For the visual and timing task, participants were asked to engage in the visual search task for a specified time interval. The difficulty level and the length of the time interval were chosen randomly. Four trials of each condition were used. When the researcher verbally announced the start of the interval, the participant engaged in the visual search task until the researcher said “stop”, indicating the end of the interval. The participant was then instructed to reproduce the time interval on the stopwatch by verbally indicating to the researcher when to start and stop the stopwatch. This performance was based on how many target letters (‘K’) the participant marked, how many target letters (‘K’) were missed, how many distracter letters were marked and how many total letters the participant scanned. The participant’s estimation of the time interval was also recorded. Afterwards the participant filled out the manipulation check questionnaire (Appendix C).

Time estimation and data analysis

Two separate within subjects multivariate repeated measures MANOVA using time interval (20, 30, 40), complexity (easy, hard) and interference type (motor, cognitive, visual) were performed on mean trials block (trial block consists of four trials of time estimation – see Figure 3). Estimation accuracy scores were calculated for each subject within each condition. These scores were obtained by dividing the logarithm of the verbal estimates by their corresponding logarithm of the actual clock times (Zakay & Tsal, 1989). A score greater than 1 indicates an over estimation while a score less than 1 indicates an under estimation.

To test the first hypothesis, stating that overall, basketball players will estimate the 30 s time interval more accurately than non-basketball players under the non-interference condition and during motor interference (easy and hard), a repeated measures MANOVA on block trials using task complexity and interference as within subject factors was performed.

To test the second hypothesis, stating that all participants will be more inaccurate in time estimation under the hard than under the simple interferences (cognitive, motor, visual), a repeated measures MANOVA was performed. The difficulty main effect across time interval and interference is the indicator for failing to reject or rejection of the hypothesis.

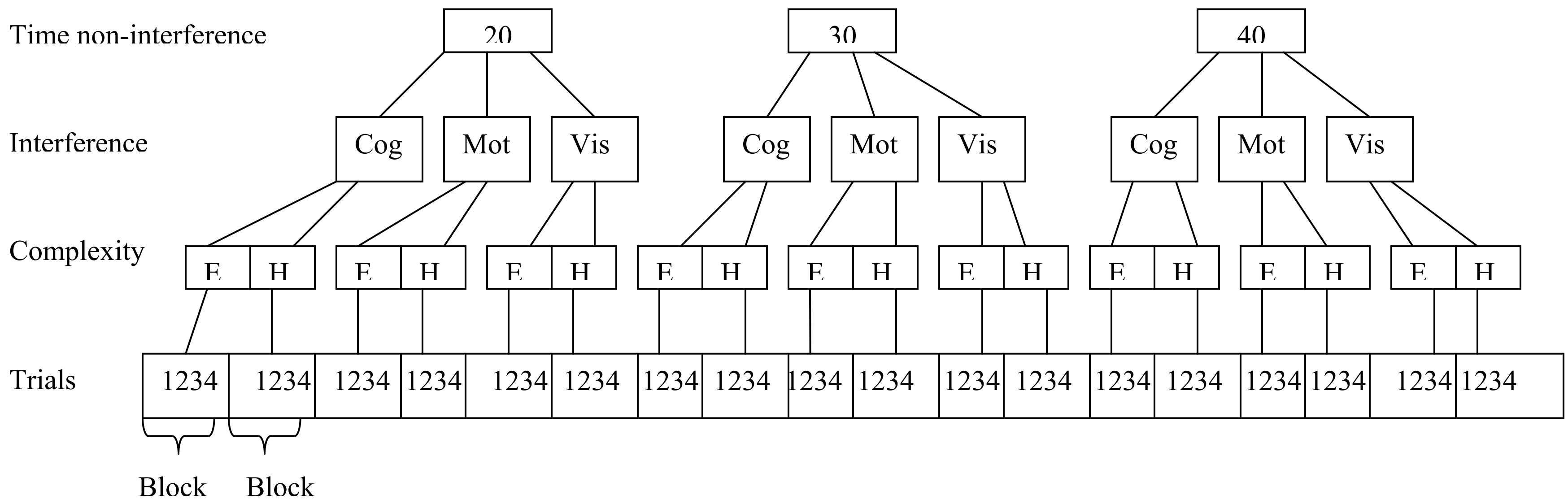

Figure 3. Conceptual Map for Trial Blocks

Cog=cognitive task, Mot=motor task, Vis=visual task; E=easy level, H=hard level

To test the third hypothesis, stating that time estimation of basketball players will be more accurate than non-basketball players for 30 s during the motor interference than for the cognitive and visual interference, under both easy and hard interference (cognitive, motor, visual) and that the estimations during the 30 s will be more accurate than the 20 s and 40 s conditions, a 3-way repeated measures MANOVA using time interval (20, 30, 40), complexity (easy, hard) and interference type (motor, cognitive, visual) was performed on mean trials block. The 3-way interaction effect between interference-type (motor, cognitive, visual), time duration (20, 30, 40), and group (basketball players versus non-basketball players) determines failure to reject or rejection of the hypothesis.

CHAPTER 4

RESULTS

Manipulation Check

Prior to examining time estimation as a function of group, interference type, time interval, and difficulty level, separate repeated measures (RM) MANOVAs were conducted to examine the cognitive, motor, and visual tasks' performance under time and no time estimation conditions. All tests were conducted with group (i.e., basketball players vs. non-basketball players) as a between subjects (BS) factor and time interval (i.e., 20 s, 30 s and 40 s), difficulty (i.e., counting backwards by 5 or 3, dribbling one or three basketballs, or visually searching for 'K' among C, O, U, Q or among V, W, X, Y), and condition (i.e., no time estimation vs. time estimation) as within subjects (WS) factors. The main effects of time interval and difficulty were significant ($p < .05$) in each test. The participants were able to perform better (i.e., count by the factor more times, dribble the basketballs longer, search more letters) as the length of the intervals increased. Also the participants performed significantly ($p < .05$) better under the easy conditions as compared to the hard conditions. These expected and obvious results are not reported; alternatively, the remaining significant and important effects are reported.

Cognitive Performance. Two different RM MANOVAs were performed for cognitive interference; one measuring the number of times the participants counted by the factor (i.e., 5 or 3) and the other measuring participants' mistakes. The first RM MANOVA for the number of times counted by the factor was conducted with group as a BS factor and time interval, difficulty (i.e., counting backwards by 5 or 3), and condition as WS factors. A non-significant effect emerged for group, $F\ (1,18) = 1.97$, $p = .18$, $\eta^2 = .10$. The significant condition effect, Wilks' $\lambda = .27$, $F(1,18) = 48.66$, $p = .00$, $\eta^2 = .73$ is presented in Figure 4.

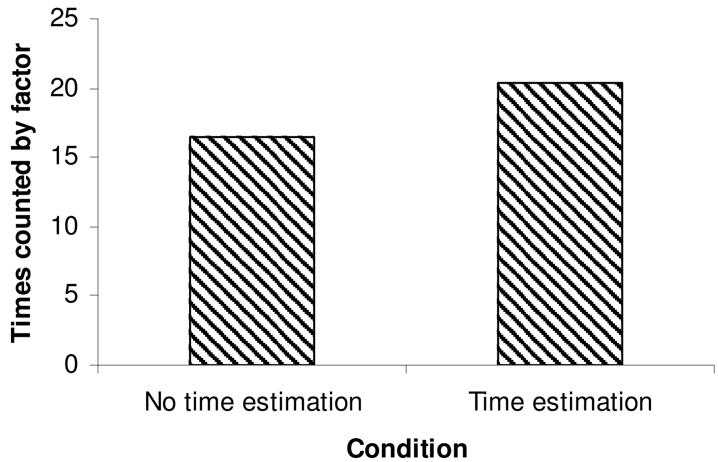

Figure 4. Mean number of times counted by factor across experimental condition.

Participants counted backwards by the factor more times when required to estimate time (M = 20.36, SD = 6.66 vs. M = 16.46, SD = 5.52, respectively; ES = .67).

The significant group by condition interaction, Wilks' $\lambda = .79$, $F(1,18) = 4.71$, $p = .04$, $\eta^2 = .21$ is shown in Figure 5.

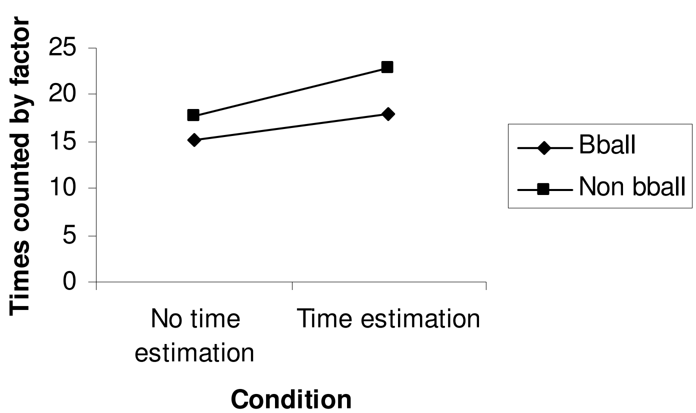

Figure 5. Mean number of times counted by factor by group across experimental condition.

Non-basketball players counted by the factor more times than basketball players in both conditions (i.e., with and without time estimation); however, the difference was greater under time estimation (M = 22.85, SD = 9.41 vs. M = 17.88, SD = 9.41, respectively; ES = .85) than under the no time estimation condition (M = 17.73, SD = 7.80 vs. M = 15.19, SD = 7.80, respectively; ES = .44).

A non-significant interaction of group by time interval was revealed, Wilks' λ = .83, F(2,17) =1.76, p = .20, η^2 = .17. However, the three way interaction of group by time interval, by difficulty level was significant, Wilks' λ = .80, F(2,17)= 2.11, p = .00, η^2 = .20 (see Figure 6).

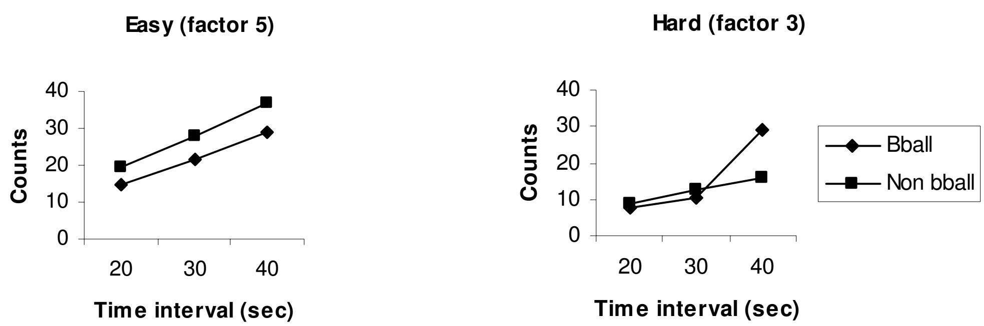

Figure 6. Mean number of times counted by factor by time interval and difficulty level.

During all three time intervals non-basketball players counted more times than basketball players by the easy factor (i.e., 5). The average number of times non-basketball players counted by five was 19.61, 28.10, and 36.73 for 20 s, 30 s, and 40 s, respectively. When counting by five basketball players on the average counted 14.94, 21.65, and 29.05 times for the three respective time intervals. Under the harder condition (i.e., counting backwards by 3), the two groups performed almost identically on the 20 s and 30 s intervals; 7.88 for basketball players and 8.65 for non-basketball players during the 20 s interval; 10.60 and 12.66 for the 30 s interval. During the 40 s interval basketball players on the average counted by three more times than non-basketball players: 29.05 vs. 15.98, respectively.

The three way group by time interval by condition interaction was non-significant, Wilks' λ = .72, F(2,17)= 3.28, p = .06, η^2 = .28. Neither was the four way interaction between group, time interval, difficulty, and condition, Wilks' λ = .93, F(2,17)= .68, p = .52, η^2 = .07.

Similar RM MANOVA for the number of mistakes was performed. The group main effect was non-significant, F (1,18) = .00, p = .99, η^2 = .00. However, the main effect of condition was significant, Wilks' λ = .67, F(1,18) = 9.06, p = .01, η^2 = .34 (see Figure 7).

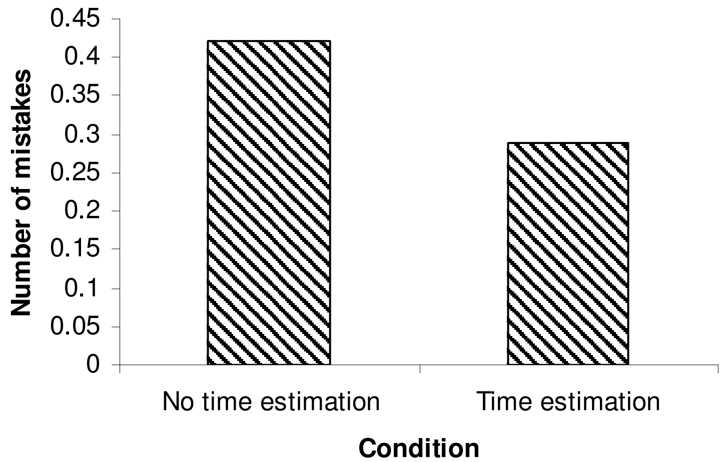

Figure 7. Mean number of mistakes across condition.

The mean number of mistakes during the no time estimation condition (M = .42, SD = .33) was greater than the mean number of mistakes during the time estimation condition (M = .29, SD = .32; ES = .43).

The main interactions that were examined were non-significant, i.e. group by condition, Wilks' λ = .95, F(1,18) = 1.01, p = .33, η^2 = .05, group by time interval, Wilks' λ = .92, F(2,17) =.75, p = .49, η^2 = .08, group by time interval by difficulty level, Wilks' λ = 1.00, F(2,17)= .00, p = .99, η^2 = .00, group by time interval by condition, Wilks' λ = .99, F(2,17) = .11, p = .90, η^2 = .01, group by time interval by difficulty by condition, Wilks' λ = .95, F(2,17) = .41, p = .67, η^2 = .05.

Motor Performance. The RM MANOVA for the total amount of time bouncing the ball by group, time interval, difficulty level (i.e., dribbling one or three balls), and condition revealed a significant main effect for group, F(1,18) = 10.07, p = .01, η^2 = .36 (see Figure 8).

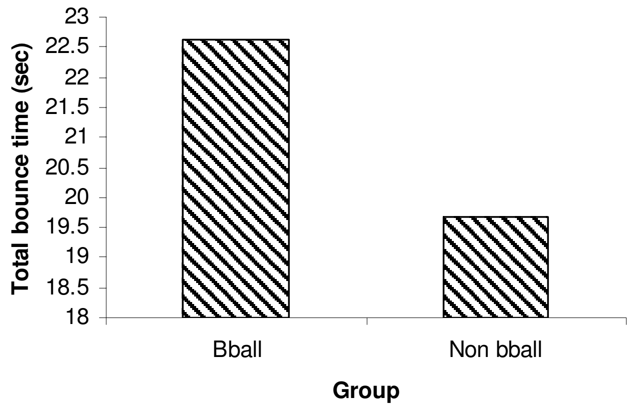

Figure 8. Mean bounce time between basketball players and non-basketball players.

Basketball players bounced on average 22.62 ± 2.93 seconds compared to 19.67 ± 2.93 seconds for non-basketball players (ES = 1.46).

A significant condition effect also emerged, Wilks' λ = .68, F(1,18) = 8.37, p = .01, η^2 = .32. Figure 9 displays this effect.

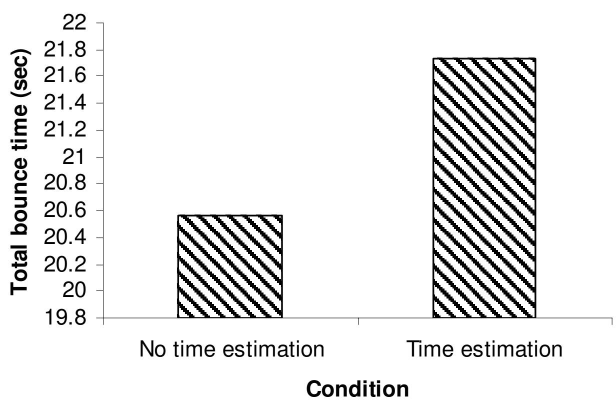

Figure 9. Mean bounce time across condition.

Bouncing time increased from an average of 20.56 ± 2.06 seconds during the no time estimation condition to a mean of 21.73 ± 2.45 seconds during the time estimation condition (ES = -.58).

The group by condition interaction was non-significant, Wilks' λ = .88, F(1,18) = 2.50, p = .13, η^2 = .12. However, the group by time interval effect reached significance, Wilks' λ = .51, F(2,17) = 8.15, p = .00, η^2 = .49 (see Figure 10).

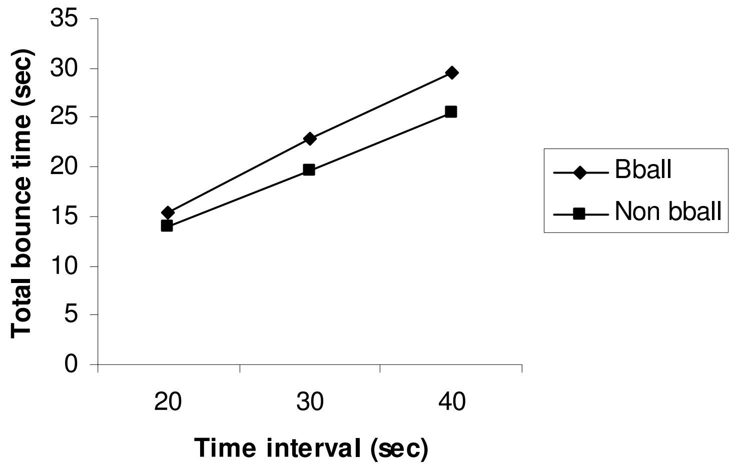

Figure 10. Difference in mean bounce time between groups by time interval.

Basketball players' bouncing time was longer than non-basketball players during all three time intervals, and increased as time interval increased. Effect sizes for the 20 s, 30 s, and 40 s intervals were .78, 1.61, and 1.98, respectively.

The group by time interval by difficulty was also significant, Wilks' $\lambda = .50$, $F(2,17) = 8.47$, $p = .00$, $\eta^2 = .50$. This three way interaction effect is displayed in Figure 11.

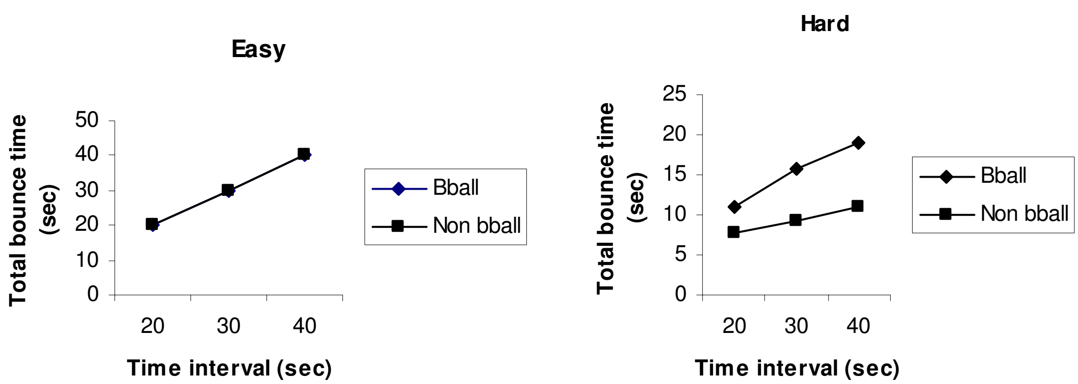

Figure 11. Mean bounce time between groups by time interval by difficulty level.

In the easy condition (i.e., dribbling one basketball) basketball players were virtually identical to non-basketball players on average bounce time during the three intervals. Under the hard condition (i.e., dribbling three basketballs), the basketball players bounced longer as the time interval increased. The standardized differences between the two groups for 20 s, 30 s, and 40 s were 1.56, 3.26, and 3.96, respectively.

The three way interaction of group by time interval by condition was non-significant, Wilks' $\lambda = .96$, $F(2,17) = .38$, $p = .69$, $\eta^2 = .04$, similarly to the four way interaction of group by time interval by difficulty by condition, Wilks' $\lambda = .95$, $F(2,17) = .46$, $p = .64$, $\eta^2 = .05$.

Visual Performance. Four RM MANOVAs were performed for visual performance; one measuring the total number of target letters marked, another for the total number of target letters missed, one for the number of distracter letters marked, and a fourth for the total number of letters scanned. The first RM MANOVA for the number of target letters marked was performed with group as a BS factor and time interval, difficulty level (i.e., searching among C, O, U, Q or among V, W, X, Y), and condition as WS factors. The main effects of group and condition were non-significant for this analysis. The group effect resulted in, $F(1,16) = 2.11$, $p = .17$, $\eta^2 = .12$; while the condition effect was, Wilks' $\lambda = .99$, $F(1,16) = .16$, $p = .69$, $\eta^2 = .01$. None of the interaction effects that were examined were significant ($p > .05$): group by condition, Wilks' $\lambda = .96$, $F(1,16) = .75$, $p = .40$, $\eta^2 = .05$, group by time interval, Wilks' $\lambda = .83$, $F(2,15) = 1.59$, $p = .24$, $\eta^2 = .18$, group by time interval by difficulty, Wilk's $\lambda = .68$, $F(2,15) = 3.53$, $p = .06$, $\eta^2 = .32$, group by time interval by condition, Wilks' $\lambda = .96$, $F(2,15) = .31$, $p = .74$, $\eta^2 = .04$, group by time interval by difficulty by condition, Wilks' $\lambda = .86$, $F(2,15) = 1.24$, $p = .32$, $\eta^2 = .14$.

The second RM MANOVA for the number of target letters missed revealed no significant ($p > .05$) main or interaction effects.

The third RM MANOVA for the number of distracter letters marked revealed a non-significant effect for group, $F(1,16) = 2.47$, $p = .14$, $\eta^2 = .13$; however the main effect of condition was significant, Wilks' $\lambda = .61$, $F(1,16) = 10.47$, $p = .01$, $\eta^2 = .13$ (see Figure 12).

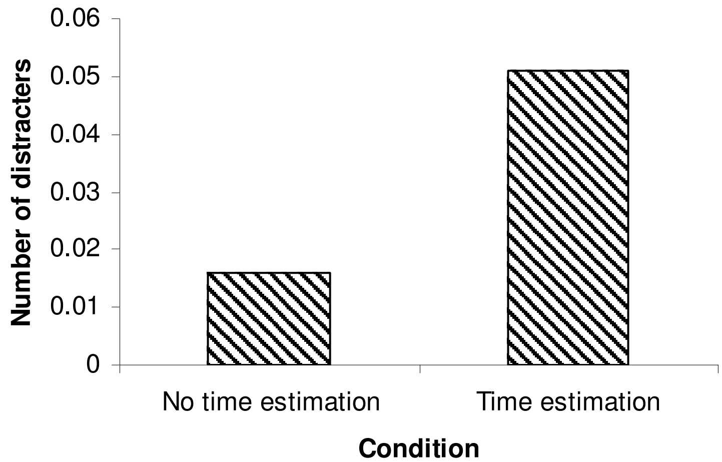

Figure 12. Mean number of distracter letters marked between conditions.

The mean number of distracters marked during the absence of time estimation was .02 $\pm$ .03 compared to .05 $\pm$ .05 for the time estimation condition (ES = -.91). Group by condition interaction effect was significant, Wilks' $\lambda = .67$, $F(1,16) = 7.86$, $p = .01$, $\eta^2 = .33$ (see Figure 13).

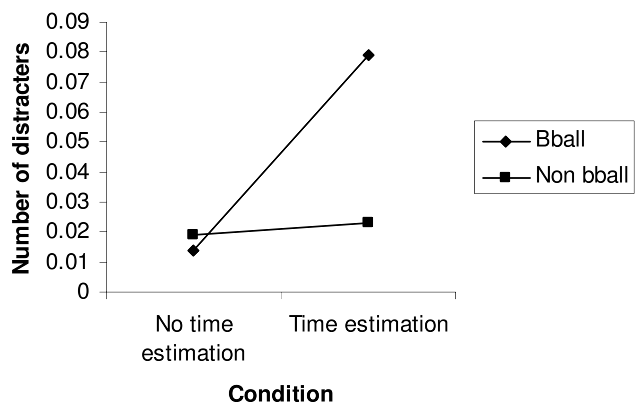

Figure 13. Difference between mean number of distracters among groups by experimental condition.

When time estimation was not present, there were minimal marked distracters in both groups; however, these increased under time estimation conditions to .08 $\pm$ .07 for basketball players and .02 $\pm$ .07 for non-basketball players (ES = 1.82).

Group by time interval was non-significant, Wilks' λ = .99, F(2,15) = .06, p = .94, η^2 = .01, and neither were group by time interval by difficulty, Wilks' λ = .93, F(2,15) = .61, p = .56, η^2 = .08, or group by time interval by condition, Wilks' λ = .96, F(2,15) = .32, p = .73, η^2 = .04.

The four way group by time interval by difficulty by condition effect was significant, Wilks' λ = .66, F(2,15) = 3.91, p = .04, η^2 = .34. This effect is shown in Figure 14.

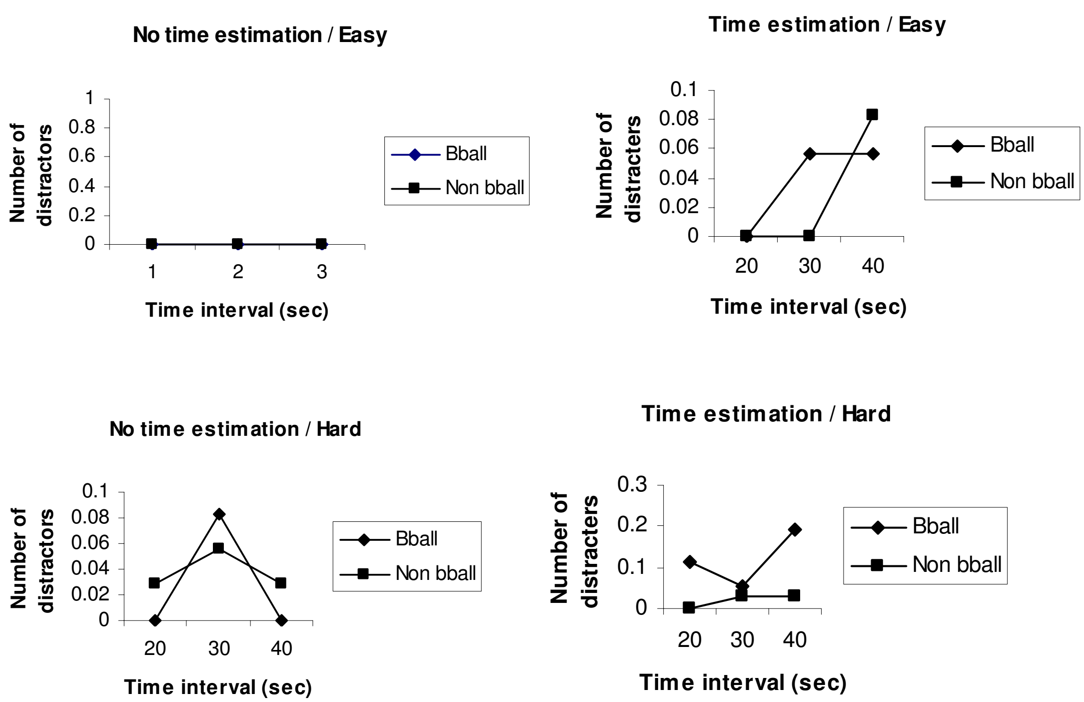

Figure 14. Mean number of distracters by group, difficulty level, time interval, and experimental condition.

When time estimation was absent and the task easy, marked distracters were non-existent in both basketball players and non-basketball players. For the time estimation condition and the easy task the two groups marked no distracters at the 20 s time interval. However basketball players marked more distracter letters during the 30 s interval, while non-basketball players marked more distracters during the 40 s interval. The non-basketball players marked more distracters during the no time estimation condition and hard level for the 20 s and 40 s time intervals; whereas the basketball players marked more distracters during the 30 s time interval. For the time estimation condition and hard level basketball players marked more distracters during the 20 s and 40 s intervals, but not during the 30 s interval. The number of distracters marked during all experimental and time condition was negligible.

The final RM MANOVA for the number of letters scanned by group, time interval, difficulty level (i.e., searching among C, O, U, Q or among V, W, X, Y), and condition revealed no group effect, $F(1,16) = 2.18$, $p = .16$, $\eta^2 = .12$ or experimental condition effect, Wilks' $\lambda = .98$, $F(1,16) = .32$, $p = .58$, $\eta^2 = .02$; nor a group by condition interaction effect, Wilks' $\lambda = .97$, $F(1,16) = .56$, $p = .46$, $\eta^2 = .03$.

The group by time interval effect was non-significant, Wilks' $\lambda = .80$, $F(2,15) = 1.92$, $p = .18$, $\eta^2 = .20$, as well as the group by time interval by difficulty level, Wilks' $\lambda = .99$, $F(2,15) = .07$, $p = .93$, $\eta^2 = .01$, the group by time interval by experimental condition, Wilks' $\lambda = .92$, $F(2,15) = .68$, $p = .58$, $\eta^2 = .08$, and group by time interval by difficulty level by condition, Wilks' $\lambda = .91$, $F(2,15) = .77$, $p = .48$, $\eta^2 = .09$.

The significant effects indicate that basketball players exhibited superior performance during the hard level of the motor task than the non-basketball players, more so with increasing time interval length; whereas, non-basketball players counted backwards by five more times in the time interval than basketball players. This difference increased with time interval duration. There were differences in condition for the cognitive and motor performance. The number of times counted by the factor and the total bounce time increased, while the number of mistakes decreased from the no time estimation condition to the time estimation condition, suggesting a possible practice effect.

Manipulation Check Questionnaire. A manipulation check questionnaire was administered to validate that the non-temporal tasks provided interference with the time estimation task. This perceived interference on time estimation was measured on a Likert-type scale (Appendix C).

A repeated measures MANOVA was performed to examine differences in perceived interference on time estimation as a function of interference type (cognitive, motor, visual) and difficulty level. These results are presented in Table 2.

Table 2

Repeated Measures MANOVA results for perceived interference effect

Effect	Wilks' λ	F	df	p	η^2
Between Subject					
Group		.16	1,18	.70	.01
Within Subject					
Interference	.95	.45	2,17	.65	.05
Difficulty level	.15	106.01	1,18	.00	.86
Interference * Group	.90	.99	2,17	.39	.10
Difficulty * Group	.83	3.64	1,18	.07	.17
Interference * Difficulty	.57	6.38	2,17	.01	.43
Interference * Difficulty * Group	.94	.59	2,17	.57	.07

Two significant ($p < .05$) effects emerged; one effect was for difficulty level (see Figure 15).

Figure 15. Mean perceived interference of time estimation along difficulty.

Participants felt that the hard tasks (i.e., counting backwards by 3, dribbling three basketballs, searching for 'K' among V, W, X, and Y) interfered with their main task of time estimation significantly more than the interference caused by the easy tasks (i.e., counting backwards by 5, dribbling one basketball, searching for 'K' among C, O, Q, and U) (M = 4.03 SD = .62 vs. M = 2.68, SD = .47, respectively; ES = 2.98). The second significant effect of this analysis was interference type by difficulty level (see Figure 16).

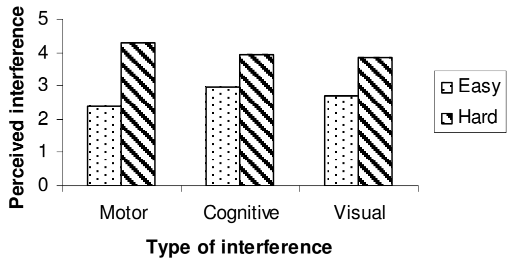

Figure 16. Mean perceived interference of time estimation as a function of difficulty level and type of interference.

For each type of interference (i.e., cognitive, motor, visual) the hard task was viewed as more interfering for time estimation than the easy task; however, the main interference differences were obtained for the motor interference (M = 2.40, SD = .69 vs. M = 4.30, SD = .72 for easy and hard respectively; ES = -4.19) compared to cognitive interference (M = 2.95, SD = .65 vs. M = 3.95, SD = .90; ES = -2.21) and visual interference (M = 2.70, SD = .82 vs. M = 3.85, SD = .89; ES = -2.54).

Preliminary Results

Prior to testing the study's hypotheses, a repeated measures MANOVA was conducted to examine differences in time estimation as a function of time interval without interference. These results are presented in Table 3.

Table 3

Repeated Measures MANOVA results for time estimation without external interference

Effect	Wilks' λ	F	df	p	η^2
Between Subject					
Group		1.71	1,18	.21	.09
Within Subject					
Time interval	.65	4.62	2,17	.03	.35
Trial	.76	1.69	3,16	.21	.24
Time interval * Group	.95	.48	2,17	.63	.05
Trial * Group	.75	1.8	3,16	.19	.25
Time interval * Trial	.63	1.30	6,13	.33	.37
Time interval * Trial * Group	.75	.73	6,13	.64	.25

The repeated measures MANOVA resulted in one significant ($p < .05$) effect of time interval. This effect is presented in Figure 17.

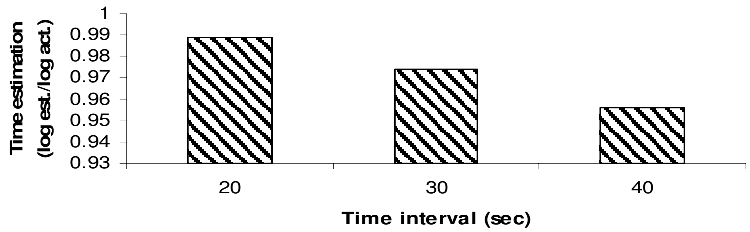

Figure 17. Mean time estimation along three different time intervals without external interference.

The time estimations were closest for the 20 s interval (M = .99, SD = .05) and were under estimated more as the time interval lengthened (M = .97, SD = .05 vs. M = .96, SD = .06 for 30 s and 40 s intervals, respectively). The standardized differences between the 20 s interval and the 30 s and 40 s intervals were .46 and .69, respectively. The standardized difference between the 30 s and 40 s intervals was .23.

Neither group nor the interaction of group by time interval by trial resulted in a significant effect ($p > .05$). Thus, the hypotheses were examined using a repeated measures MANOVA with group (i.e., basketball players vs. non-basketball players) as a BS factor and time interval (i.e., 20 s, 30 s, 40 s), interference (i.e., cognitive, visual, motor) and difficulty (i.e., easy, hard) as repeated WS factors.

Hypothesis Testing

The first hypothesis stated that overall, basketball players will estimate the 30 s time interval more accurately than non-basketball players under the non-interference condition and during motor interference (easy and hard). This hypothesis was not fully verified due to the non-significant effect of group by time interval with no external interference, Wilks' $\lambda = .95$, $F(2,17) = .48$, $p = .63$, $\eta^2 = .05$. The second hypothesis stated that all participants will be more inaccurate in time estimation under the hard than under the easy difficulty level for all types of interferences (cognitive, motor, visual). The third hypothesis stated that time estimation of basketball players will be more accurate than non-basketball players for 30 s during the motor interference than for the cognitive and visual interference, under both easy and hard interference (cognitive, motor, visual) and that the estimations during the 30 s will be more accurate than the 20 s and 40 s conditions.

The three hypotheses were examined using a repeated measures MANOVA with group (i.e., basketball players vs. non-basketball players) as a BS factor and time interval (i.e., 20 s, 30 s, 40 s), interference (i.e., cognitive, visual, motor) and difficulty level (i.e., easy, hard) as repeated WS factors. These results are presented in Table 4.

Table 4

Repeated Measures MANOVA results for time estimation with external interference

Effect	Wilks' λ	F	df	p	η^2
Between Subject					
Group		.14	1,18	.71	.01
Within Subject					
Time interval	.17	42.88	2,17	.00	.84
Interference	.22	29.66	2,17	.00	.78
Difficulty	.41	25.70	1,18	.00	.59
Time interval * Group	.67	4.16	2,17	.03	.33
Interference * Group	.88	1.19	2,17	.33	.12
Difficulty * Group	.87	2.71	1,18	.12	.13
Time interval * Interference	.72	1.43	4,15	.27	.28
Time interval * Difficulty	.88	1.15	2,17	.34	.12
Interference * Difficulty	.74	3.05	2,17	.07	.26
Time interval * Interference * Group	.81	.89	4,15	.50	.19
Time interval * Difficulty * Group	.98	.18	2,17	.84	.02
Interference * Difficulty * Group	.98	.17	2,17	.85	.02
Time interval * Interference * Difficulty	.68	1.75	4,15	.19	.32
Time interval * Interference * Difficulty * Group	.80	.92	4,15	.48	.20

The repeated measures MANOVA resulted in four significant ($p < .05$) effects: time interval, interference type, difficulty level, and time interval by group interaction. The effect of time interval is presented in Figure 18.

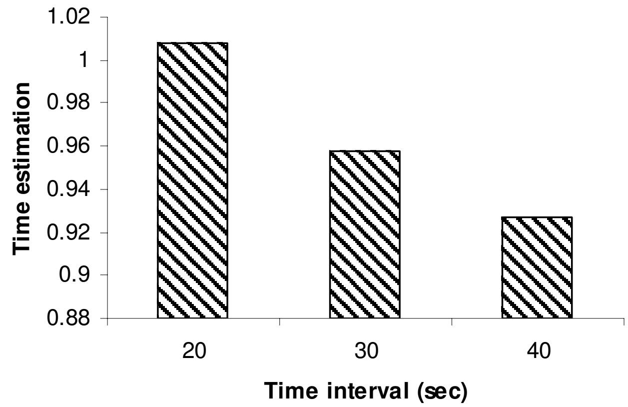

Figure 18. Mean time estimation for three time intervals.

Participants slightly overestimated the 20 s interval. The mean accuracy score for the 20 s interval was 1.01 or 20.49 seconds (i.e., a 2.5% overestimation). The 30 s and 40 s intervals were underestimated. The 40 s interval was underestimated more so than the 30 s interval. The mean accuracy score for the 30 s interval was .96 or 26.01 seconds, while the mean accuracy score for the 40 s interval was .93 or 30.56 seconds. The mean estimation for the 30 s interval was a 13.3% underestimation whereas the mean estimation for the 40 s interval was a 23.6% underestimation. The standardized differences between the 20 s interval and the 30 s and 40 s intervals were .82 and 1.31, respectively. The standardized difference between the 30 s and 40 s intervals was .49.

The effect of group by time interval by interference was non-significant, Wilks' $\lambda = .81$, $F(4,15) = .89$, $p = .50$, $\eta^2 = .19$, resulting in a rejection of hypothesis 1 that basketball players will estimate the 30 s time interval more accurately than non-basketball players during motor interference (easy and hard). This non-significant effect also results in a rejection of hypothesis 3 stating that basketball players will be more accurate than non-basketball players for 30 s during the motor interference than for the cognitive and visual interference, under both easy and hard interference (cognitive, motor, visual). However, time estimations across both groups were more accurate during the motor interference. This significant type of interference effect is displayed in Figure 19.

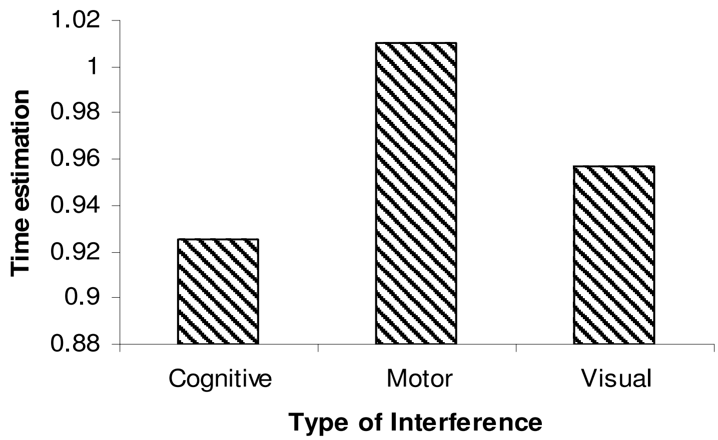

Figure 19. Mean time estimation for three types of interference.

On average, participants estimated time most accurately under the motor interference and the least accurate under the cognitive condition. The mean accuracy score under the motor interference was 1.01 indicating almost perfect time estimation. Under the visual interference the mean accuracy score was .957, an underestimation. A mean accuracy score of .925 under the cognitive interference shows a greater underestimation as compared to the other conditions. The standardized differences between motor interference and cognitive and visual interference were 1.39 and .87, respectively. The standardized difference between visual and cognitive interference was .52.

Data supported hypothesis 2 that all participants will be more inaccurate in time estimation under the hard than under the easy difficulty level for all types of interferences (cognitive, motor, visual). This significant effect of difficulty is presented in Figure 20.

Figure 20. Mean time estimation as a function of difficulty.

Participants suffered the most in time estimation accuracy under the hard conditions as compared to the easy conditions. The mean accuracy coefficient under the hard conditions was .952 while the mean accuracy score for the easy conditions was .977. The effect size was -.41.

The significant time interval by group interaction effect is displayed in Figure 21.

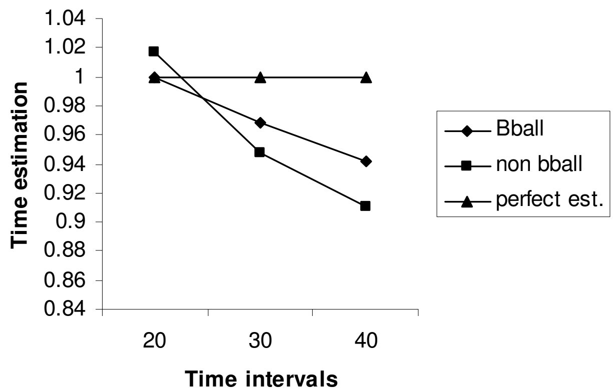

Figure 21. Mean time estimation by groups and by time intervals.

On average, the basketball players were more accurate on time estimations than non-basketball players on all three time intervals. This difference was smallest during the 20 s interval in which, on average basketball players were almost perfect time estimators (i.e., mean accuracy score = .999 or 19.94 seconds), while non-basketball players overestimated a bit (i.e., mean accuracy score = 1.017 or 21.05 seconds). Both groups underestimated the 30 s and 40 s intervals; non-basketball players more so than the basketball players. The basketball players underestimated with a mean accuracy score of .968 (i.e., 26.91 seconds) on the 30 s interval versus .948 (i.e., 25.14 seconds) for the non-basketball players. For the 40 s interval the basketball players had a mean accuracy score of .942 (i.e., 32.30 seconds) versus .911 (i.e., 28.81 seconds) for the non-basketball players. This data does not support hypothesis 3 stating that the basketball players' estimations during the 30 s will be more accurate than the 20 s and 40 s conditions; the closest estimations were during the 20 s interval. However, basketball players were more accurate than non-basketball players under all types of interference for all three intervals; indicating that they experienced less interference than non-basketball players from the non-temporal distracter tasks. This is evidenced by the non-significant group effect under the no interference condition.

An independent t-test was conducted at each time interval to examine mean differences in time estimation between the two groups. The difference between basketball players and non-basketball players at the 20 s interval is non-significant, $t(df = 18) = -.598$, $p = .557$. The difference between the two groups at the 30 s interval, $t(df – 18) =.647$, $p = .526$, and the 40 s interval, $t(df=18) = 1.085$, $p = .292$ were non-significant.

CHAPTER 5

DISCUSSION

The purpose of this study was to extend time estimation research into the sport domain, specifically basketball, as well as to introduce estimation of a familiar time interval. Prior research has provided a great deal of evidence for an attention-based model for time estimation (Zakay, 1992; Zakay, 1993a; Zakay 1993b; Zakay, 1998; Zakay, Nitzan, & Glicksohn, 1983; Zakay & Tsal, 1989). Proponents of this attentional model argue that time estimation is directly related to the amount of attention that is allocated for processing the passage of time (Zakay, 1992). In order to validate this model various manipulations aim at diverting attention to other sources than to a concurrent temporal task.

Brown (1997) studied automaticity in time estimation, with automaticity referring "to performing a highly practiced task with few or no processing resources" (p.1125). Brown and Bennett (2002) found that practice on a non-temporal task resulted in less interference in timing from this concurrent non-temporal distracter task. They indicated that practice on the task leads to a shift in cognitive processing such that the task uses fewer additional resources as different parts of the performance becomes automatized.

The current study extended the automatization theory, and applied it to a situation in which the timing task is more automatic, and thus results in less interference from non-temporal tasks. Specifically, it was hypothesized that basketball players who regularly engage in estimation of 30 s (through estimation of 30 s on the shot clock) will be more accurate in their time estimations, and will be less influenced by non-temporal distracter tasks than non-basketball players.

Prior to examining time estimation, we first explored differences in the cognitive, motor, and visual tasks' performances under both the no time estimation and time estimation condition. Findings indicated that basketball players were obviously better during the hard motor task than non-basketball players, more so with increasing time interval length. For the cognitive performance, non-basketball players counted backwards by five more times in the time interval than basketball players; difference increased with task duration. This was an unexpected effect, since the random selection of participants was assumed to control for any group differences in cognitive performance. For the visual performance, specifically the number of distracter letters marked, there was a group difference; however, the number of distracters marked for each condition was negligible. These group differences in non-temporal task performance were not considered to be an important factor affecting time estimation accuracy. Better performance on the non-temporal task (i.e., counting backwards by the factor more times, dribbling the basketballs longer, or marking less distracter letters) does not necessarily imply that there is a different amount of attention being allocated to the non-temporal task. There were differences for the cognitive and motor performance between the first session (i.e., no time estimation) and the second session (i.e., time estimation). Both groups improved their performance on the cognitive and motor tasks from the first to the second session. The sessions were separated by one week; however, these results suggest a possible practice effect.

The manipulation check questionnaire was utilized in order to validate that the non-temporal tasks provided interference with the time estimation task. The results from the manipulation check indicated that all tasks did interfere with the participant's ability to estimate the time interval. As expected, participants viewed the hard tasks as interfering more with their estimation of the time intervals than the easy tasks. Participants perceived the biggest interference difference from the easy to hard task during the motor interference. Furthermore, during the easy motor task all participants performed perfectly, while during the hard motor task there were significant differences in performance between groups. This displays a larger gap of difficulty between the easy and hard level as compared to the cognitive and visual tasks. Given that all of the non-temporal tasks resulted in interference, we were able to test the study's hypotheses.

The first hypothesis stated that basketball players would estimate the 30 s time interval more accurately than non-basketball players when interference is absent, and during motor interference (easy and hard). This hypothesis was not supported by the data.

During Session 1 (conducted with no interference), there were no differences between the two groups on their estimations of the 30 s time interval. Similarly, during session 2 (with interference), the groups were comparable on their estimations of the 30 s time interval. Because the time estimations were performed under a reproduction methodology, information about the actual length of the time intervals (i.e., 20 s, 30 s, or 40 s) was ignored. Basketball players are familiar with the 30 s time interval as they regularly experience it through the 30 s shot clock. However, applying this methodology, they were not aware of the actual length of the time interval, and therefore might not realize that they were estimating a familiar time interval. This could account for the similarities in time estimation of the 30 s interval between groups.

The second hypothesis claimed that all participants would be more inaccurate in time estimation under the hard than under the simple interferences regardless of being cognitive, motor, or visual. This hypothesis was verified. The mean accuracy coefficients under the hard and easy conditions were .952 and .977, respectively, which supports the notion that an increase in informational load results in a shortened perceived duration (Zakay, 1989), and shortening of perceived time occurs when task difficulty increases (Harton, 1938a; Smith, 1969; Zakay et. al., 1983). According to Brown (1997) during reproduction the shortening of perceived time results from fewer temporal cues being perceived, which results in shortened time estimations.

The third hypothesis stated that basketball players would be the most accurate across all conditions and interferences during the motor interference, specifically for 30 s. Moreover, it was assumed these estimations would be more accurate in basketball players than in non-basketball players. This was not supported by the data. Although basketball players did not differ in time reproduction of 30 s under the condition of motor interference than under the conditions of cognitive and visual interference, both groups were more accurate under motor interference for all three time intervals than under cognitive and visual interference conditions. The mean accuracy score for both groups under the motor interference was 1.01 indicating almost perfect time estimation. Under the visual interference the mean accuracy dropped to .957, an underestimation, and to .925 under the cognitive interference. Attentional model theorists claim that time estimation is directly related to the amount of attention that is allocated for processing the passage of time (Zakay, 1992). Previous studies have found that cognitive tasks involving mental arithmetic (Burnside, 1971; Wilsoncroft & Stone, 1975) and visual search tasks (Fortin, Rousseau, Bourque, & Kirouac, 1993, Experiment 2) provided interference and resulted in a shortening of estimated time durations compared to control conditions. The current study added the interference of a motor task. This motor task may not require a similar extent of the attention needed for time estimation as the cognitive and visual tasks. Therefore, the greatest accuracy of time estimation occurred under motor interference.

Hypothesis 3 also claimed that basketball players would be most accurate during the 30 s interval than the 20 s and 40 s intervals. This was not supported by the data; basketball players very accurately reproduced the 20 s interval. The estimations were underestimated more so as the time interval lengthened. Non-basketball players had a similar tendency to underestimate the interval more so as it lengthened. These results partially support Vierdort's law that short time intervals are overestimated while long intervals tend to be underestimated (Woodrow, 1951).

Overall, basketball players were more accurate time estimators than non-basketball players across all three-time intervals under all types of interference, in accordance with Hepworth's (1968) results where track athletes produced specified time intervals more accurately than non-athletes. It is possible that basketball players are more familiar and aware of various time intervals due to the numerous time constraints during a basketball competition (i.e., thirty seconds to get a shot off, three seconds in the lane, five seconds to inbound the ball), and therefore experience less interference from non-temporal distracter tasks than non-basketball players.

Interestingly, this study indicates that positive transfer of time estimation accuracy occurred during the 20 s and 40 s time intervals. This suggests a general timing ability by basketball players which would not be predicted by the current literature. Various studies have found expertise to be highly specific (Chase & Simon, 1973; Ericsson & Kintsch, 1995). Chase and Simon (1973) found that chess players were better able to recall briefly presented chess positions than less experienced players. However, this superior memory skill did not transfer to the situation in which the pieces were presented randomly. Similarly, it is expected that basketball players would be superior during the 30 s time interval as they are familiar with estimating this interval and therefore possess mental representations of this time period. Interestingly, basketball players displayed superior time estimation accuracy among the 20 s and 40 s time intervals; even though they were not familiar with these time intervals and thus would not exhibit mental representations of them in order to mediate the judgment of the time periods. This suggests that a type of "farther" transfer occurred. According to Barnett and Ceci (2002) near transfer is more readily empirically supported than far transfer. The terms near and far transfer refers to the extent that the two tasks contain similar elements. Near transfer occurs between two tasks that involve many similar elements, while far transfer occurs between tasks with a fewer number of similar elements. It is possible that transfer transpired during the 20 s and 40 s time intervals because they are very similar to the 30 s interval. It is assumed that as the tasks are more dissimilar (i.e., the time interval to be estimated becomes progressively longer) the time judgment superiority will diminish.

Basketball players displayed a superior ability to estimate time under conditions that were somewhat different from real-life basketball competition. Similarly to competition, the study's condition provided interference with the timing task. Transfer likely occurred because the time estimation task and the time constraints in competition share some elements.

Limitations and future research

A limitation of this study is the small sample size (n = 20). Utilizing a larger sample size would increase generalizability, and allow researchers to make stronger statements about time estimation in athletes.

Another possible limitation of the study was the distinction between basketball players and non-basketball players. Some basketball players participated in both basketball and soccer, while some of the non-basketball players participated in soccer and/or track and field. The involvement in soccer for both basketball players and non-basketball players may have been a confounding variable. Similarly, the involvement of track may have been a confounding variable as it is reasonable to assume that track athletes may be better time estimators than non-track athletes (Hepworth, 1968). Therefore, in the future it may be beneficial to have participants that play only basketball and a matched sample of participants that do not engage in a sport that involves time variables.

Another limitation of the study was the environment in which the testing was conducted. Due to limited resources, the study was conducted outside on a high school track. Therefore, the weather conditions were uncontrollable and some participants may have felt uncomfortable with the heat, and thus shortened their time estimations.

Another potential limitation of the study was the length of the time intervals in combination with the reproduction method. Occasionally, when participants were reproducing the interval they would forget that they were supposed to indicate the end of the interval. This distraction was apparent from their comments that they were influenced by extraneous thoughts. In future research, the production method could be utilized. When employing the production method the participant would be instructed to perform the non-temporal task (i.e., counting backwards, dribbling basketballs, searching for a target letter) for a certain time interval (i.e., 20 s, 30 s, 40 s), and would be asked to tell the researcher to stop the stopwatch when she perceived the passage of the specified time interval. During reproduction, the participant engages in the non-temporal task until the researcher instructs her to stop. Consequently, she instructs the researcher when to start and stop the stopwatch indicating the perceived length of the interval. It is during this interval that the participants were being distracted. The use of the production method could reduce the possibility of being distracted, because the empty time interval that appears in the reproduction methodology would not exist in production. Also, the estimation of shorter time intervals may alleviate this problem, as the participants would be required to concentrate for a shorter amount of time.

Limited research on time estimation has been conducted in the sport domain and could benefit from analysis in this area. A possible future direction is to utilize the production method for a familiar time interval. Research would also benefit from investigating different and possibly shorter time intervals (i.e., 3 seconds in the lane, 5 seconds to inbound the ball, 10 second back court violation).

APPENDIX A

Parental Consent Form for Minors

Dear Parent:

I am a graduate student under the direction of Professor Gershon Tenenbaum, PhD in the Department of Educational Psychology and Learning Systems at Florida State University. I am conducting a research study to better understand time estimation among basketball players.

Your child's participation will involve estimating different time intervals while performing a concurrent task. The concurrent task will involve counting backwards, dribbling basketballs, or visually searching for a target letter. There will be four trials for each condition. Your child's participation will involve two sessions separated by one week. Each session will last 30-45 minutes. Your child will also be asked to fill out a pencil and paper questionnaire upon completion of these tasks. These questionnaires will be kept in a locked filing cabinet. The researcher will have access to this information and it will be destroyed by August 1st, 2005. All of your child's answers to the questions will be kept confidential to the extent allowed by law.

Your participation, as well as that of your child, in this study is voluntary. If you or your child choose not to participate or to withdraw from the study at any time, there will be no penalty, (it will not affect your child's treatment). The results of the research study may be published, but your child's name will not be used.

Although there may be no direct benefit to your child, the possible benefit of your child's participation is providing the researcher with valuable insights into time estimation.

If you have any questions concerning this research study or your child's participation in the study, please call me at (607) 765-0385 or Dr. Tenenbaum at (850) 644-8791.

Sincerely,

Julia Gould

* * * * * * *

I give consent for my child ____________________________ to participate in the above study.
(child's name)

Parent's Name: ________________________________

Parent's Signature ________________________________ Date ________________

If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Committee, Institutional Review Board, through the Vice President for the Office of Research at (850) 644-8633.

APPENDIX B

PLAYERS' INFORMED CONSENT

I freely and voluntarily and without element of force or coercion, consent to be a participant in the research project entitled "Time Estimation Among Basketball Players".

This research is being conducted by Julia Gould, a graduate student in the department of Educational Psychology and Learning Systems at Florida State University majoring in sport psychology. I understand that the purpose of this research project is to better understand time estimation among basketball players.

I understand that I will be asked to estimate different time intervals while performing a concurrent task. I understand that the concurrent task will involve counting backwards, dribbling basketballs, or visually searching for a target letter. I understand that I will be performing four trials for each condition. I understand that I will be participating in two sessions separated by one week. Each session will last 30-60 minutes.

I understand that I will be asked to fill out a pencil and paper questionnaire upon completion of these tasks. These questionnaires will be kept in a locked filing cabinet. I understand that only the researcher will have access to this information and it will be destroyed by August 1st, 2005.

I understand that my participation is totally voluntary and I may stop participating at anytime. All of my answers to the questions will be kept confidential to the extent allowed by law. My name will not appear on any of the results.

I understand that there is a minimal level of risk involved with this study. My participation in this research study will provide the researcher with valuable insights into time estimation.

I understand that this consent may be withdrawn at any time without prejudice, penalty, or loss of benefits to which I am otherwise entitled.

I understand that I may contact Julia Gould (607) 765-0385 or the Institutional Review Board (Human Subject's Committee) (850) 644-8633, with any further questions I may have regarding the research or my rights. Alternatively, I may contact Dr. Gershon Tenenbaum, Florida State University, Department of Educational Psychology and Learning Systems at (850) 644-8791. The results of the study will be sent to me upon my request.

I have read and understand this consent form.

______________________________ ___________

Participant Date

APPENDIX C

MANIPULATION CHECK QUESTIONNAIRE

Directions: Please read each of the following statements listed below and indicate how much you feel the task interfered with estimating the time interval.

1. I feel dribbling one basketball interfered with my estimation of the time interval

1	2	3	4	5
Not at all	A little	Somewhat	A lot	A great deal

2. I feel dribbling three basketballs simultaneously interfered with my estimation of the time interval

1	2	3	4	5
Not at all	A little	Somewhat	A lot	A great deal

3. I feel counting backwards by 3 interfered with my estimation of the time interval

1	2	3	4	5
Not at all	A little	Somewhat	A lot	A great deal

4. I feel counting backwards by 5 interfered with my estimation of the time interval

1	2	3	4	5
Not at all	A little	Somewhat	A lot	A great deal

5. I feel searching for the target ‘K’ among C,O,Q,U interfered with my estimation of the time interval

1	2	3	4	5
Not at all	A little	Somewhat	A lot	A great deal

6. I feel searching for the target ‘K’ among V,W,X,Y interfered with my estimation of the time interval

1	2	3	4	5
Not at all	A little	Somewhat	A lot	A great deal

APPENDIX D

HUMAN SUBJECTS RESEARCH APPROVAL

Florida State
UNIVERSITY

Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2763
(850) 644-8673 · FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 3/16/2005

To:
Julia Gould
600 Victory Garden Drive , Apt N114
Tallahassee, FL 32301

Dept.: **EDUCATIONAL PSYCHOLOGY AND LEARNING SYSTEMS**

From: **Thomas L. Jacobson, Chair**

Re: **Use of Human Subjects in Research**
Time Estimation Among Basketball Players

The forms that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and two members of the Human Subjects Committee. Your project is determined to be Expedited per 45 CFR § 46.110(b) 7 and has been approved by an accelerated review process.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If the project has not been completed by **3/15/2006** you must request renewed approval for continuation of the project.

You are advised that any change in protocol in this project must be approved by resubmission of the project to the Committee for approval. Also, the principal investigator must promptly report, in writing, any unexpected problems causing risks to research subjects or others.

By copy of this memorandum, the chairman of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols of such investigations as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Protection from Research Risks. The Assurance Number is IRB00000446.

Cc: Gershon Tenenbaum
HSC No. 2005.172

APPENDIX E

HUMAN SUBJECTS RESEARCH APPROVAL REVISED

Florida State
UNIVERSITY

Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2763
(850) 644-8673 · FAX (850) 644-4392

APPROVAL MEMORANDUM (for change in research protocol)

Date: 6/22/2005

To:
Julia Gould
600 Victory Garden Drive , Apt N114
Tallahassee, FL 32301

Dept: EDUCATIONAL PSYCHOLOGY AND LEARNING SYSTEMS

From: Thomas L. Jacobson, Chair

Re: Use of Human subjects in Research
Project entitled: Time Estimation Among Basketball Players

The memorandum that you submitted to this office in regard to the requested change in your research protocol for the above-referenced project have been reviewed and approved. Thank you for informing the Committee of this change.

A reminder that if the project has not been completed by 3/15/2006, you must request renewed approval for continuation of the project.

By copy of this memorandum, the chairman of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols of such investigations as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Protection from Research Risks. The Assurance Number is IRB00000446..

cc: Gershon Tenenbaum
APPLICATION NO. 2005.172

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