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## Anticipation Timing as a Function of Expertise and Effector-Specific Training

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To the Graduate Council:

I am submitting herewith a thesis written by Greg Young entitled "Anticipation Timing as a Function of Expertise and Effector-Specific Training." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Sport Studies.

Jeffrey T. Fairbrother, Major Professor

We have read this thesis and recommend its acceptance:

Craig A. Wrisberg, Clare E. Milner

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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ANTICIPATION TIMING AS A FUNCTION OF EXPERTISE  
AND EFFECTOR-SPECIFIC TRAINING

A Thesis  
Presented for the  
Master of Science  
Degree  
The University of Tennessee, Knoxville

Greg Young

May, 2008

## Dedication

This thesis is dedicated to my mother Joan, my father Allan, and my brother Steven. You are the reason that I strive to be all that I can be and provide the inspiration that I need to be my best. The constant source of help, support, and advice that you have given me throughout my life is without measure. I am forever in your debt.

Love always.

## Acknowledgements

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I would also like to thank my remaining committee members, Dr. Craig Wrisberg, and Dr. Clare Milner, for their input. Thank you for the time and effort that you have given, not only towards my thesis, but to my continuing development as a scholar and a person. One day I hope to make this process seem as effortless as you do.

I would like to thank all of the participants who took part in the study. Simply put, this could not have been done without you.

Finally, I would like extend my thanks to all of the faculty, staff, and fellow students that have made the completion of my master's degree such a pleasure. Many Thanks.

## Abstract

Ericsson, Krampe, and Tesch-Römer (1993) suggested that 10,000 hours of deliberate practice is needed to attain expertise. Consequently, it would be expected that expert soccer players who possess a high level of proficiency in intercepting a ball with their feet would demonstrate superior anticipation timing performance with the feet compared to novices who lack training. On the other hand, Keele, Ivry, and Porkorny (1987), and Studenka and Zelaznik (2008) provided support for a centrally controlled process for timed movements. If true, it would be expected that experts' anticipation timing performance would be superior to novices' regardless of the effector used.

The purpose of this study was to examine the anticipation timing performance of expert soccer players with that of novices using the preferred and non-preferred feet and hands. Participants were required to perform a simple movement task replicating the reception of a pass in soccer by intercepting the apparent motion of a series of lights on a Bassin anticipation timer using the preferred and non-preferred hands and feet. Participants completed 60 trials total at three different velocities (4-mph, 5-mph, & 6-mph). Dependent variables were constant error (CE) and variable error (VE).

For CE a Group x Limb interaction ( $p = .022$ ) revealed that experts were more accurate in the foot condition than the novices. This interaction also revealed that experts performed similarly in both the foot and the hand conditions suggesting that experts were

able to increase the accuracy of performance with the feet to more closely match that of the hands due to the effects of deliberate practice. For VE a Main Effect for Group ( $p = .002$ ) revealed that Experts were less variable in anticipation timing performance than novices. This supports the notion of a central timing mechanism for variability. Results suggest that variability in anticipation timing performance is influenced by a common central timing process, while accuracy is dependent upon effector specific training.



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## Chapter 1

### Introduction

#### *Background of the Study*

The sport of soccer is incredibly demanding. Federation Internationale de Football Association (FIFA) regulations dictate that matches include two uninterrupted 45-minute halves separated by a brief half-time interval of no more than 15 minutes (Federation Internationale de Football Association, 2007). In addition to the physical demands of such lengthy games, soccer is a mentally demanding activity requiring players to maintain a task-specific focus throughout the game (e.g., monitoring the changing positions of opposing players and tracking the ball) while also engaging in higher order cognitive activities related to strategy and tactics. Soccer not only incorporates different fundamental movement skills requiring high levels strength, power, endurance, and flexibility (e.g., running and jumping), it also requires special skills that are unique to the game (e.g., dribbling and heading the ball). Players are often required to play the ball using different parts of the body, including the feet, legs, thighs, chest, and head. These body parts may be utilized in several different ways depending on the demands of the moment. For example, the chest may be used to intercept and control and oncoming ball or to simply block an opponent's shot. The feet are used to execute a variety of skills, including passing, shooting, and tackling. Almost all of the specialized skills required in soccer depend on the player's capability to intercept the moving ball.

This capability, called anticipation timing or coincident anticipation timing, requires a person to track the motion of an object, estimate when it will arrive at a specific location, and precisely coordinate his or her movement to intercept the object when it arrives at that location (Belisle, 1963; Tresilian, 1995). Anticipation timing is a fundamental component of the passing, receiving, and shooting skills required during regulation play in soccer.

It has been suggested that in order to reach an expert level of performance in any domain an individual must accumulate the equivalent of 10,000 hours of deliberate practice (Ericsson, Krampe, & Tesch-Römer, 1993). This *10,000-hr principle* is consistent with the findings related to the amount of accumulated practice for international-level soccer players (Helsen, Hodges, Van Winckel, & Starkes, 2000; Helsen, Starkes, & Hodges, 1998). As a result of such extensive practice, high level soccer players typically demonstrate great proficiency in skills requiring anticipation timing. However, even international level players often develop a preference regarding which foot they will use to execute skills (Carey et al., 2001). Presumably this preference is based on some understanding (perhaps implicitly) that the preferred foot is more effective than the non-preferred foot in executing soccer skills. If this is true, then it would be expected that expert soccer players would spend more time in deliberate practice of activities using the preferred foot and this, in turn, would increase the proficiency of this effector in executing soccer skills. If so, the most trained effector (i.e., preferred foot) should be the most proficient in executing soccer skills requiring anticipation timing.

However, because anticipation timing is common to so many soccer skills, it might be expected that it reflects a general timing process. This idea is consistent with evidence suggesting that timed movements may be controlled by a common central timing process (Keele, Ivry, & Pokorny, 1987; Keele, Pokorny, Corcos, & Ivry, 1985). However, more recent work has reported that some aspects of timed movements may depend upon a central process while others may depend upon effector-specific training (Studenka & Zelaznik, 2008). These findings raise the possibility that elite soccer players may possess a general proficiency in anticipation timing that is greater than that of novices. If true, it might be expected that highly trained soccer players would be more proficient than novices in anticipation timing, regardless of the effector being used. Indeed, several studies have shown reliable differences in anticipation timing performance between trained and untrained individuals (Del Rey, Waughalter, & Whitehurst, 1982; Del Rey, Whitehurst, & Wood, 1983; Del Rey, Wughalter, & Carnes, 1987; Del Rey, 1989; Ripoll & Latiri, 1997; Benguigui & Ripoll, 1998; Williams, Katene, & Fleming, 2002). Because these studies examined performance with only one effector, the extent to which differences in anticipation timing are due to a common central timing process or to effector-specific training is still unknown.

#### *Purpose of the study*

The purpose of this study was to examine the anticipation timing performance of expert soccer players with that of novices using the preferred and non-preferred feet and hands. According to Ericsson et al.'s (1993) deliberate practice framework, anticipation timing skill using any given effector should be highly dependent upon the amount of deliberate practice accumulated with that effector. Thus, it would be expected that

trained soccer players would show superior anticipation timing performance with their feet when compared to novices. In addition, because soccer players typically display a foot preference, it might be expected that anticipation timing performance with the preferred foot would be superior to performance with the non-preferred foot. According to the work suggesting that timed movements may be governed by a common central process, it might also be expected that trained soccer players would show superior anticipation timing performance compared to novices, regardless of the effector used.

### *Hypotheses*

If anticipation timing skill is dependent upon a common central process that generalizes across effectors, it is expected that:

1. Anticipation timing performance will be significantly more accurate (lower CE), for the Expert group than for the Novice group regardless of limb or preference.
2. Anticipation timing performance will be significantly less variable (lower VE), for the Expert group than for the Novice group regardless of limb or preference.

If anticipation timing skill is dependent upon effector-specific deliberate practice, it is expected that:

3. Anticipation timing performance with the feet will be significantly more accurate (lower CE) for the Experts than for the Novices.
4. Anticipation timing performance with the feet will be significantly less variable (lower VE) for the Experts than for the Novices.

5. For Experts, performance with the preferred foot will be significantly more accurate (lower CE) than with the non-preferred foot.
6. For Experts, performance with the preferred foot will be significantly less variable (lower VE) than with the non-preferred foot.
7. For Novices, performance with the hands will be significantly more accurate (lower CE) than with the feet.
8. For Novices, performance with the hands will be significantly less variable (lower VE) than with the feet.

### *Assumptions*

The following assumptions were made regarding the present study.

1. All participants put forth their best effort.
2. All participants completed the experimental task to the best of their ability.
3. The operational definition of expert represented a valid classification.
4. The operational definition of novice represented a valid classification.
5. Participants had no previous knowledge of the experimental task.

### *Delimitations*

The present study was delimited in the following ways.

1. All subjects were female.
2. All subjects were college age.
3. Participation was voluntary.
4. The study was conducted in a laboratory setting.

### *Definition of terms*

The following definitions and, in some cases operational definitions, were employed in this study.

#### *Anticipation timing.*

The ability to correctly estimate the arrival of a stimulus at a point in time, in which a response can be programmed to occur and executed simultaneously (Tresilian, 1995). Also referred to as coincidence timing.

#### *Coincidence timing.*

The ability to execute a motor response that coincides with the arrival of an object at a designated point in time and space (Belisle, 1963). Also referred to as anticipation timing.

#### *Constant error (CE).*

The average deviation from a target with respect to sign (CE) (Schmidt & Lee, 1999). The primary measure of anticipation timing error used in this study, measured as the difference in milliseconds (ms) between the arrival of the limb at the target lamp and the lighting of the target lamp.

#### *Variable error (VE).*

A measure of variation around the mean CE. A measure of the consistency of performance (Schmidt & Lee, 1999). Measured in ms.

#### *Expert.*

Experts in this study were current intercollegiate female soccer players or women that had competed at the intercollegiate level in the previous two years.



*Novice.*

Novices in this study were college-age females with no formal training in the sport of soccer or other interceptive sports (e.g., basketball, volleyball, softball, racquetball, field hockey, lacrosse) at any time during the previous 3 years.

*College-age women.*

College-age women in this study were individuals currently enrolled in a higher education setting (college). For the current study all participants were currently enrolled at The University of Tennessee.

*Interceptive ball sports.*

Any sports that require the manipulation of a ball. These sports include but are not limited to: soccer, tennis, volleyball, basketball, softball, lacrosse, and field hockey.

*Interceptive limb.*

The specified limb used to break the photocell beam during the execution of the movement task.

*Stepping foot.*

The foot placed on the back timing mat then transferred to the front timing mat during execution of the movement task. The foot contralateral to the interceptive limb.

*Contralateral limb.*

The limb on the side of the body opposite to the stepping foot.

*Reaction time.*

The elapsed time from the onset of a stimulus until the initiation of a response (Schmidt & Lee, 1999). The operational definition of reaction time for the current study was the elapsed time from the initiation of the stimulus light to the initiation of the

performance movement by the participant (i.e., lifting of the stepping foot from the back timing mat).

*Movement time.*

The elapsed time from the initiation of a movement until its completion (Schmidt & Lee, 1999). In the current study, the elapsed time between the lifting of the foot from the back timing mat and the planting of the same foot on the front timing mat.

## Chapter 2

### Literature Review

The following section provides a review of relevant literature as it pertains to the current study. The following topics are covered in the chapter: a) deliberate practice; b) foot preference; c) central control of timing performance; d) anticipation timing; e) the role of experience in anticipation timing.

#### *Deliberate Practice*

Previous literature suggests that 10,000 hours of deliberate practice are needed to achieve an expert level of performance (Ericsson, Krampe, & Tesch-Römer, 1993). This principle is generally considered to be equivalent to the requirement of ten years of deliberate practice (Simon & Chase, 1973). The term *deliberate practice* refers to specific training situations in which the goal of the completed activities is to improve a clearly defined specific element of performance (Ericsson, Krampe, & Tesch-Römer, 1993). Expertise and deliberate practice have been examined in several performance domains. Simon and Chase (1972) studied the performance of international-level chess players and found that achievement of the level of Grandmaster required at least a decade of deliberate chess practice. The 10,000 hour principle has also been demonstrated in the domain of musical composition. Hayes (1981) examined the amount of time from the beginning of music study to the first composition of an outstanding musical piece. The results revealed that on average 20 years of deliberate practice was needed to understand

the complexities of instruments, chords, and musical timbres in order to produce a level of work qualified as expert standard. It stands to reason that the principle of deliberate practice would hold true in the sporting domain, as well as these other performance domains. Indeed, Ericsson et al.'s (1993) deliberate practice principle has been supported in the sports domain in general (for a review see Starkes & Ericsson, 2003), as well as in the sport of soccer (Helsen, Starkes, & Hodges, 1998).

Helsen, Starkes, and Hodges (1998) examined deliberate practice in Belgian soccer players. International, national, and provincial soccer players completed questionnaires designed to assess previous patterns of training in developing expertise. The participants reported when practice was first initiated and the amount of time spent in deliberate soccer practice and soccer-related activities. The amount of time in practice included the amount of time spent in individual as well as team practice. Participants estimated the number of hours of practice completed in blocks of three-year intervals, from the beginning of soccer participation to the present time. Participants also recalled the duration of their off-season for each three year interval throughout their careers. Results revealed that these soccer players began practicing at 5 years of age ( $M = 5.3$  years). For both the international and national level soccer players, the difference between the starting age and the current peak performance level for individual and team practice averaged 15 years. These findings supported the deliberate practice principle for achieving expertise proposed by Ericsson et al. (1993).

### *Foot Preference*

Soccer players tend to exhibit a foot preference when playing the game, even those performing at elite international levels. Although evidence regarding foot preference in soccer is largely anecdotal, Carey et al. (2001) identified foot preference when examining a range of soccer skills by examining footage of individual soccer players during games of the 1998 FIFA World Cup. Across all soccer skills including successful execution of dribbling, shooting, passing, and ball control skills, players displayed a foot preference. If the deliberate practice principle is valid, then it might be expected that the most highly trained effector of an individual should perform the best at any given skill. It might be expected that the preferred foot of soccer players is the most highly trained effector due to large amounts of specific training that has been completed using this effector.

### *Central Control of Timing Performance*

There are several studies that have investigated the proposition that timed movements are controlled by a common timing process (Keele, Ivry, and Pokorny, 1987; Keele, Pokorny, Corcos, & Ivry, 1985; Robertson et al., 1999; Zelaznik et al., 2005; and Studenka & Zelaznik, 2008). Evidence for central timing has been found for a metronome paced tapping task using the finger and the foot (Keele, Pokorny, Corcos, & Ivry, 1985, Exp. 1; Keele, Ivry, & Pokorny, 1987, Exp.1), in a paced tapping task completed in conjunction with the production of a criterion force by the effector (Keele, Ivry, & Pokorny, 1987, Exp.1), in the dominant and non-dominant hand for a metronome paced tapping task (Studenka and Zelaznik, 2008, Exp. 1), within paced tapping and paced circle drawing tasks across differing interval durations (Robertson et al., 1999,

Exp. 3), and in the first replication of an interval, for both paced tapping and paced circle drawing tasks (Zelaznik et al., 2005). However, some previous research has also revealed results that do not support a central timing mechanism. For example, Zelaznik et al. (2005) did not find support for a central timing process for interval replication over four intervals in paced tapping and circle drawing tasks. Additionally, Robertson et al. (1999, Exp. 1) failed to support a central timing mechanism for a paced tapping task over two differing rates (400 ms & 800 ms).

#### *Anticipation Timing*

Anticipation timing is a common feature of many skills that are prevalent in the sport of soccer (e.g., passing, shooting, and receiving the ball). Anticipation timing has been defined as the ability to correctly estimate the arrival of a stimulus at a point in time in which a response can be programmed to occur and executed simultaneously (Tresilian, 1995). Also termed coincident timing behavior, anticipation timing has been defined as the ability to make a motor response coincide with the arrival of an object at a designated point in time and space (Belisle, 1963). The role of experience in anticipation timing performance has been examined in several studies. A number of these have shown that experienced or trained participants have better anticipation timing performance than untrained participants (Del Rey, 1982; Del Rey, 1989; Del Rey, Wughalter, & Whitehurst, 1982; Del Rey, Wughalter, Whitehurst, & Barnwell, 1983; Del Rey, Whitehurst, & Wood, 1983; Del Rey, Wughalter, & Carnes, 1987).

### *The Role of Experience in Anticipation Timing*

Several studies have been conducted to explore the role of experience in anticipation timing performance. For example, Del Rey, Wughalter, and Whitehurst (1982) instructed participants to press a button so that it coincided with the arrival of a moving light at the end of the track-way of a Bassin Anticipation Timer. Sixty female participants were divided in two groups based on the extent of their previous experience in open sport skills. The novice group had no current or previous involvement in open sport skills while the experienced group was regularly involved in open sport skills for at least a year. Results revealed the experienced group demonstrated better anticipation timing performance than the novice group at higher velocities of stimulus presentation and when stimulus velocities were presented randomly. Experienced participants also displayed lower variable error and absolute error during the acquisition phase than did the novices. These results suggest that previous experience in open sport skills can produce higher levels of novel task anticipation timing performance.

In a second study observing the effects of experience on performance in an anticipation timing task, Del Rey, Whitehurst, and Wood (1983) examined 80 (40 male, 40 female) school age children ( $M = 8.33$  yrs) with varying levels of sport experience. An experienced group consisted of half of the boys and half of the girls who had participated for more than two seasons in organized sports that required anticipation timing, including soccer, football, basketball, softball, and baseball. A novice group consisted of children that had participated in the previously mentioned sports for one season or less. A simple button pressing task was used to assess anticipation timing performance. Results of the study demonstrated that the more experienced subjects were more accurate and less

variable over-all than the novice subjects, supporting the findings of the previous study (Del Rey et al., 1982) and suggesting that experience may also have an impact on performance of an anticipation timing task for younger participants.

In a third study, Del Rey, Wughalter, and Carnes (1987) used the same anticipation timing task with a group of 72 females divided into two groups. The experienced group consisted of individuals who, at the time of testing, were regularly involved in open sport skills and had been participating regularly in their sport for five years immediately prior to the test. Less experienced subjects were those who had not been engaged in organized open sport skills or actively involved in sport, for at least five years prior to the study. Results again supported the notion that experienced participants perform better on tasks that require anticipation timing skills than do inexperienced participants.

A study by Del Rey (1989) examined the influence of specific training on the performance of an anticipation timing task. Sixty-four females were randomly assigned to two groups. One group received training in the prediction of a moving object in the sport of tennis, while the other group received no training. A button pressing task was used in order to assess anticipation timing skill. Acquisition and retention phases were completed prior to the introduction of the four-week training program. Participants in the trained group received one hour of instruction, two times per week, for four weeks. Upon completion of the training, a second retention test was administered. Results of the study demonstrated that the group of participants that took part in the training program decreased their variable error scores compared to those who did not receive training. The



results of this study strengthen the notion that open skill sports training can facilitate performance on laboratory tasks involving anticipation timing (Del Rey, 1989).

The initial work studying the effects of experience on the performance of an anticipation timing task has defined experience to be any form of participation in physical activity programs or open sport skill settings regardless of the actual activity. Since that time the focus of study has been narrowed to examine at the effects of a specific sport experience on anticipation timing performance. For example, Ripoll and Latiri (1997) studied the effects of table tennis expertise on the performance of an anticipation timing task. The study compared expert table tennis players (French national team players) to novice performers. The expert performers had practiced table tennis skills intensively for more than ten years, while the novice group had not practiced table tennis or had practiced only very occasionally. The experimental task required participants to synchronize a movement with their right hand so that it occurred with the arrival of an apparent motion along a track way of LED lights. Participants completed the task using 2 different presentation velocities. The two velocities were chosen to match game-like speeds that would occur for a ball approaching from a forehand drive in table tennis (Ripoll & Latiri, 1997).

Results showed no differences in the performance of the expert and novice groups in a constant velocity condition. However, the expert group performed significantly more accurately than the novice group during a constant deceleration trajectory task. Ripoll and Latiri (1997) suggested that the more accurate performance on the constant deceleration task by the expert performers may have been due to the variability of trajectory velocities that table tennis players are subjected to during the course of a

game/practice session. Being exposed to these changing task demands allows the expert performers to adapt their visual system in order to deal with these changing demands (Ripoll & Latiri, 1997). The findings of the study suggested that the specific training that the expert group had received from extensive practice undertaken in table tennis had facilitated more accurate novel task performance.

Other research examining the effects of sport-specific experience on anticipation timing tasks has been undertaken using participants with extensive tennis training. For example, Benguigui and Ripoll (1998) used the same task as Ripoll and Latiri (1997) to compare the performance of 24 experienced tennis players to that of 24 novices who had only minimal participation in tennis and other related ball sports. Participants in each category were divided into four groups of six performers each depending on their age (7-, 10-, 13-years old, and adults). Participants attempted to complete the experimental task at three different velocity conditions: constant velocity condition (4.17 m/s), constant deceleration, and constant accelerated condition. All three conditions shared the same arrival velocity and viewing time (4.17 m/s and 700 ms, respectively). The conditions were selected to match the kinematic properties of a tennis ball during a game situation. Results revealed that variability in coincidence timing performance for younger participants improved under the influence of specific tennis practice.

More recently Williams, Katene, and Fleming (2002), attempted to increase the ecological validity of anticipation timing measures while examining experience effects. They achieved this by creating a task that required a movement response similar to those found in a game situation. Participants (N = 162, ages 10-15 years) were all part of a professional tennis coaching program. Participants represented five different age groups

(10-11.5, 12, 13, 14, & 15 years old) with each age group then subdivided by skill level (high, medium, low) as determined by two experienced professional coaches using the National Tennis Rating Program. The experimental task required participants to remove their tennis racquet from a neutral resting position and execute the backhand groundstroke to break a photoelectric beam upon the arrival of the stimulus along a trackway. The target point of coincidence for each individual represented the point at which contact with a tennis ball would occur during the normal execution of the stroke. Participants completed the task in response to one of two constant velocities (2.68 m/s and 5.36 m/s).

The results revealed a significant skill level x age x gender x trial block interaction on all measures (constant error, variable error, absolute error, and total error). Follow-up analysis revealed that the youngest and least skilled group demonstrated less proficient performance, suggesting that experience as well as age produces superior anticipation timing performance.

Taken together, the results of earlier research suggest that experience in open sport skill settings and the completion of sport specific training can result in more accurate performance of a novel anticipation timing task. However, it is not known if performance of these tasks is governed by a central timing mechanism or the effects of deliberate practice as proposed by Ericsson et al. (1993). The purpose of the current study was to examine the performance of experts and novices across preference and limbs to determine if anticipation timing skill is generalizable across effectors, as suggested by the notion that timing skill is governed by a central mechanism, or

dependent upon the specific training of the specific effector that is used, as suggested by the deliberate practice principle.

## Chapter 3

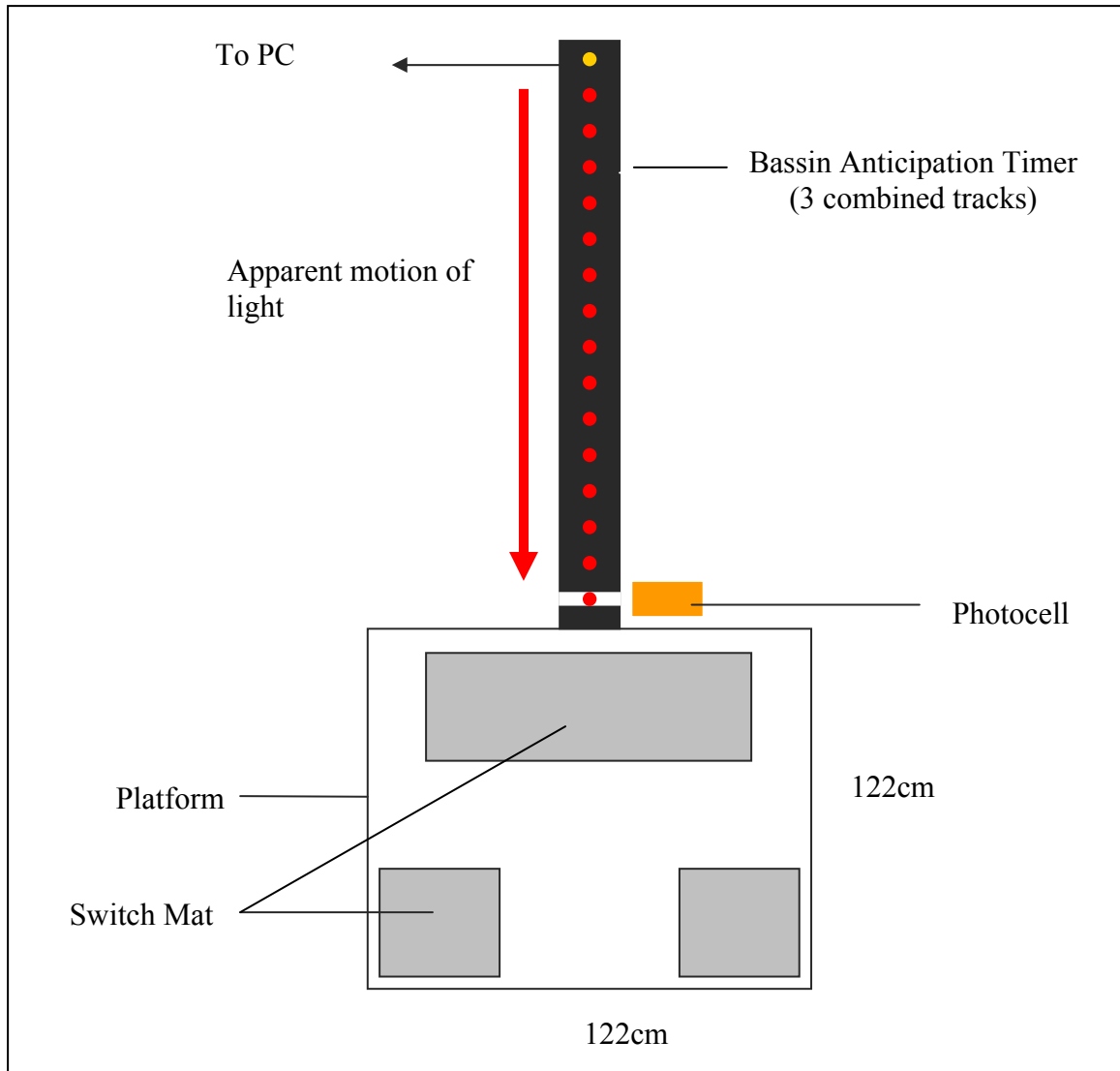
### Methods and Procedure

#### *Participants*

Participants were 24 College-age women selected from the student body of the University of Tennessee. Participants were naïve to the purposes of the study and had no prior experience with the experimental task. Half of the participants (n=12) were considered novices, and were operationally defined as individuals having received no formal training in soccer or other interceptive sports (e.g., basketball, volleyball, softball, racquetball, field hockey, lacrosse) at any time during the previous 3 years. The other half of the participants (n=12) were considered expert soccer players, which was operationally defined as individuals who were currently competing in the sport of soccer or who had competed at the collegiate level during the previous 2 years. The expert participants averaged 15.3 years of soccer experience.

#### *Apparatus and Task*

Figure 1, depicts the testing apparatus which consisted of a Bassin Anticipation Timer (Lafayette Instrument Company model 35575, Lafayette, Indiana) interfaced with a personal computer, two Lafayette Multi-Function Timers (model 54035A), three pressure sensitive switch mats, and an Infrared Control System (photocell switch) (model 63501IR). The 230-cm anticipation timer track consisted of three standard tracks and housed a total of 49 lamps. The first lamp was amber and served as a warning light at



*Figure 1.* The experimental apparatus viewed from a birds-eye perspective, the tripod housing of the photocell is omitted for clarity.

the beginning of each trial. The remaining lamps were red. The last lamp on the track served as the target lamp and was identified by a white strip that was clipped over the lamp. A wooden platform (122 cm<sup>2</sup>) was positioned on the floor adjacent to the target-lamp end of the anticipation timer track. The platform was raised 13 cm from the surface of the floor so that participants could readily pass their foot over the target lamp without making contact with the track. The platform housed three switch mats, which were used to measure reaction time (RT) and movement time (MT). Two of the mats were positioned in the rear corners of the platform and served as starting positions for the stepping foot which initiated the required movement. (e.g., the left foot for right-footed kicks and for right-handed strikes). The third pad was positioned towards the front of the platform where the stepping foot of the performer was to be planted to facilitate either the kick or arm swing using the contralateral limb. The track was positioned on the floor so that the target light was centered on the front edge of the platform and the track was aligned in the sagittal plane (i.e., perpendicular to the front edge of the platform). A photocell switch was placed above the track so that it would be activated by passing a foot or hand over the target lamp. The photocell was positioned at a height that would allow unobstructed movement by the participants. The sequential illumination of the lamps created the a pattern of apparent motion of the light towards the participant. The placement of the track in the participants' sagittal plane was done to increase the ecological validity of the study because most soccer passes are received in this plane. Research has shown that presenting the stimulus in this plane increases consistency and accuracy in anticipation timing performance (Hart, 2004).

### *Pilot Study*

A pilot study involving two participants was completed to familiarize the primary investigator with the experimental procedures and to identify potential problems with the apparatus and data recording methods. Participants in the pilot study also provided feedback to the primary investigator regarding the clarity of the experimental instructions.

### *Procedure*

Consent was granted by the head coach of the University of Tennessee Lady Volunteers soccer team prior to approaching team members for participation. During a team meeting the requirements of the study were explained and players were invited to participate. Novice participants were recruited from classes in the University of Tennessee's Physical Education Activity Program and by word of mouth. All participants provided informed consent prior to taking part in the study. Upon completion of the informed consent, participants were asked a series of demographic questions to determine hand and foot preference, years of soccer experience, position played in soccer, and any other formal experience or participation in other interceptive ball sports. Participants were provided with written instructions describing the experimental procedures and were familiarized with the experimental apparatus. The task required participants to watch the apparent motion of the light and move to break the beam of the photocell at the same time the target lamp was illuminated. Depending upon the experimental condition, the beam was broken with the right hand, left hand, right foot, or left foot. Participants were told that the goal of the task was to be as accurate as possible in intercepting the light while completing the movement correctly. The



investigator then demonstrated the movement task under all four combinations of the limb and preference: preferred foot (PF), non-preferred foot (NPF), preferred hand (PH), and non-preferred hand (NPH). Participants were given the opportunity to ask questions and then completed 6-8 practice trials. Participants completed at least one practice trial in each experimental condition. Qualitative feedback regarding technique was provided by the investigator to ensure that each participant executed the task correctly. For the PH and NPH conditions, participants were instructed to step forward and break the photocell beam with a sweeping arm motion. Participants were instructed to take a large step forward and use a relatively brief arm movement to make the movement consistent with the accepted technique in soccer coaching of instructing players to plant their non-striking foot as close as possible to the ball.

During data collection, no feedback was provided regarding technique or anticipation timing performance. Participants completed 20 trials under three different velocity conditions (4-, 5-, and 6-mph). The three velocity conditions were selected to replicate the speed of passes during a soccer match (Brillinger, 2007). The order of velocity conditions was counterbalanced across participants in each group. Participants were not informed about the different velocity conditions. Each block of 20 trials contained five trials in each of the four preference and limb condition combinations (PH, NPH, PF, NPF). The order of presentation of these combinations was counterbalanced across participants. The inter-trial interval was approximately 10 s.

Each trial began with the participant positioned in the center of the platform. The investigator provided a verbal prompt (“Ready”), in response to which the participant stood so that the foot contralateral to the intercepting limb was placed on the switch mat

closest to that foot. For example, if either the right foot or right hand was used to intercept the stimulus, then the left foot was placed on the switch mat located in the left rear corner of the platform. If the left foot or left hand was used as the intercepting limb, then the right foot was placed on the switch mat located in the right rear corner. To initiate a trial, the investigator pressed a trigger switch, which illuminated the amber warning light for 2 seconds. After that, the apparent motion of the light commenced. To correctly execute the task, the movement required participants to step forward onto the front switch mat with the foot that was located on one of the rear switch mats while swinging the contralateral limb (foot or hand) forward to break the beam of the photocell. Participants were instructed to make the movement in one fluid motion. At the completion of each trial, the participant returned to the center of the platform and waited for further instruction.

## Chapter 4

### Results

#### *Data Treatment*

Constant error (CE), reaction time (RT), and movement time (MT) were recorded for each trial. Variable error (VE) was calculated for preference and limb combination for each participant. Constant error was used as a measure of anticipation timing accuracy and was considered to be the overall index of skill performance. VE was the measure of each participant's variation in anticipation timing performance around her mean CE for each condition. VE was used as a measure of performance consistency. RT was the elapsed time (in sec) from the onset of the stimulus to the removal of the stepping foot from the first timing mat. MT was the elapsed time from the removal of the stepping foot to the planting of the stepping foot on the front timing mat. Due to an unforeseen technical problem in the recording of RT, the interpretation of both RT and MT data was compromised. Therefore, RT and MT were not analyzed.

Initial data screening revealed that two participants in the Expert group were noticeably less accurate than the rest of the group. Data was subsequently screened for outliers trial by trial. Outliers were identified as scores falling beyond three standard deviations from the mean of the group. In the Expert group, two participants each produced three outlier scores. In addition, for each of these participants, two of the outliers occurred within a single condition (i.e., 5PH and 6NPF). Therefore, the data of

these participants was excluded and was replaced with that of two additional participants. Data screening also revealed that one participant in the Novice group produced five outlier scores. This participant was also replaced. These procedures resulted in 14 participants in each of the two experimental groups. Mean scores for each condition (i.e., PH, PF, NPH, NPF) were calculated across all three presentation velocities for constant error (CE) and variable error (VE).

### *Statistical Analysis*

CE and VE were analyzed using separate 2 (group) x 2 (preference) x 2 (limb) analysis of variance (ANOVA) with repeated measures on the last 2 factors. If violations of the sphericity assumption were detected,  $p$ -values involving a repeated measures factor were reported with the Greenhouse-Geisser  $df$  adjustment. Follow-up testing was completed using Sidak post hoc procedures. The region of rejection was set at  $p < .05$  for all analyses.

### *Results*

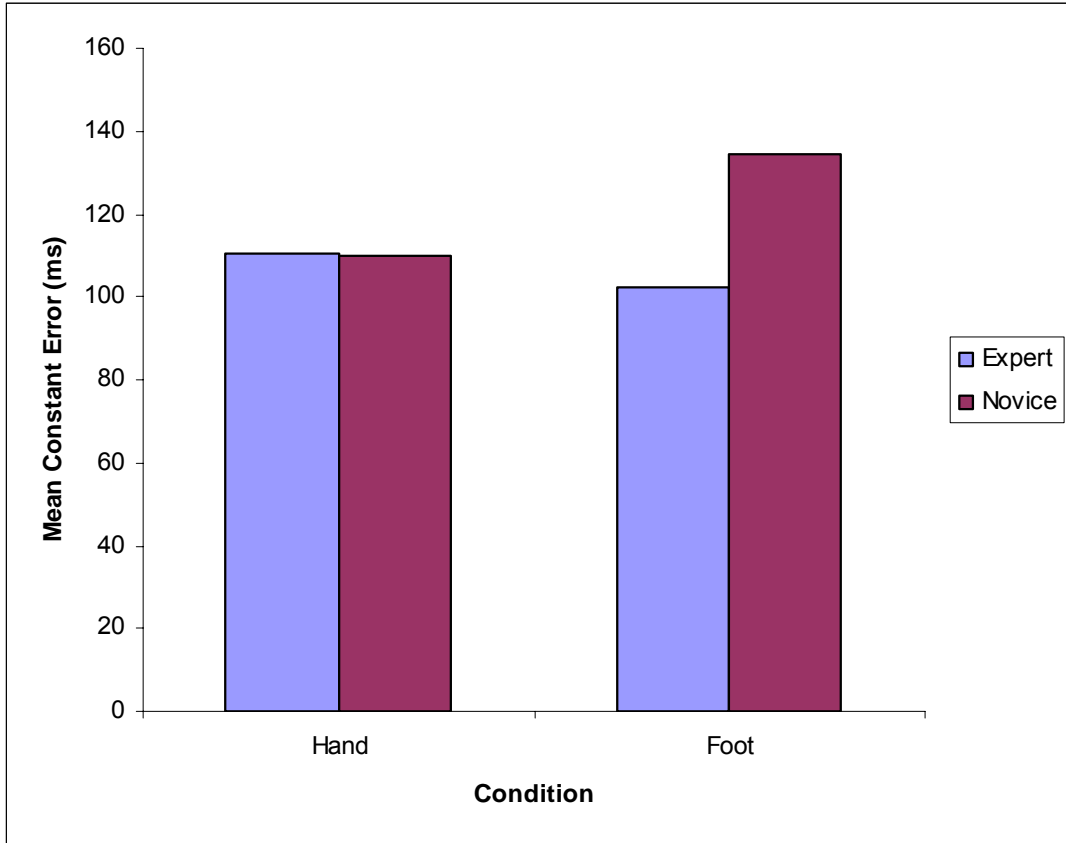
#### *Constant Error*

The ANOVA for CE (see Table 1) revealed a significant Group x Limb interaction,  $F(1, 26) = 5.95, p = .022, \eta^2 = .19$ . Performance in the expert group was very similar in both the hand ( $M = 110.39\text{ms}; SD = 60.46\text{ms}$ ) and the foot ( $M = 102.21\text{ms}; SD = 46.37\text{ms}$ ) condition (see Figure 2). However, novice performance was much more accurate with the hand ( $M = 109.78\text{ms}; SD = 41.54\text{ms}$ ) than with the foot ( $M = 134.62\text{ms}; SD = 45.40\text{ms}$ ). Post hoc testing revealed accuracy was significantly higher for the hand than for the foot for the Novice group ( $p = .016$ ). However, for Experts there was no difference in accuracy between the foot and the hand conditions ( $p = .402$ ).

Table 1

*Analysis of Variance for Constant Error*

Source	<i>df</i>	<i>F</i>	<i>p</i>	Partial $\eta^2$
Between Subjects				
Group	1	.85	.364	.03
Error	26			
Within Subjects				
Preference	1	.48	.493	.02
Group x Preference	1	4.11	.053	.14
Error(preference)	26			
Limb	1	1.50	.231	.06
Group x Limb	1	5.95	.022	.19
Error(limb)	26			
Preference x Limb	1	.21	.652	.01
Group x Preference x Limb	1	1.91	.179	.07
Error(Preference x Limb)	26			



*Figure 2.* Mean constant error scores for Foot and Hand conditions in the Expert and Novice groups.

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There were no other significant effects although the Group x Preference interaction barely failed significance,  $F(1,26) = 4.11, p = .053, \eta^2 = .14$ . Group means as a function of preference and limb are shown in Table 2. For preferred limbs, Experts ( $M = 112.97$  ms;  $SD = 53.73$  ms) performed similarly to novices ( $M = 118.94$  ms;  $SD = 36.61$  ms). For non-preferred limbs, Experts ( $M = 99.63$  ms;  $SD = 52.30$  ms) produced a substantially lower mean CE score than the Novices ( $M = 125.46$  ms;  $SD = 44.81$  ms).

#### *Variable Error*

The ANOVA for VE (see Table 3) revealed a significant main effect for group,  $F(1,26) = 11.68, p = .002, \eta^2 = .31$ . Group means for VE as a function of preference and limb are shown in Table 4. Anticipation timing performance for the Expert group ( $M = 43.90$  ms;  $SD = 10.29$  ms) was less variable than for the Novice group ( $M = 58.75$  ms;  $SD = 12.58$  ms). No other effects were significant ( $p > .05$ ).

Table 2

*Group Means and Standard Deviations for Constant Error*

Preference	Limb	Group	Mean	Std. Deviation
Preferred	Foot	Expert	112.62	50.27
		Novice	129.48	36.09
	Hand	Expert	113.31	61.01
		Novice	108.41	47.78
Non-Preferred	Foot	Expert	91.79	43.46
		Novice	139.77	59.74
	Hand	Expert	107.47	64.95
		Novice	111.16	44.13



Table 3

*Analysis of Variance for Variable Error*

Source	<i>df</i>	<i>F</i>	<i>p</i>	Partial $\eta^2$
Between Subjects				
Group	1	11.68	.002	.31
Error	26			
Within Subjects				
Preference	1	.94	.340	.04
Group x Preference	1	.07	.792	.003
Error(preference)	26			
Limb	1	2.02	.167	.07
Group x Limb	1	1.83	.187	.07
Error(limb)	26			
Preference x Limb	1	.13	.719	.01
Group x Preference x Limb	1	.63	.436	.02
Error(Preference x Limb)	26			

Table 4

*Group Means and Standard Deviations for Variable Error*

Preference	Limb	Group	Mean	Standard Deviation
Preferred	Foot	Expert	40.89	6.31
		Novice	62.62	30.56
	Hand	Expert	44.59	24.49
		Novice	50.79	12.92
Non-Preferred	Foot	Expert	47.17	14.22
		Novice	65.25	25.35
	Hand	Expert	42.97	16.85
		Novice	56.33	15.34

## Chapter 5

### Discussion

#### *Discussion*

The purpose of the current study was to examine the anticipation timing performance of expert soccer players and novices using the preferred and non-preferred feet and hands to determine the extent to which this skill is generalizable across effectors or dependent upon effector-specific training. Two sets of hypotheses were forwarded based on previous literature. Some research has indicated that various aspects of timed movements are controlled by a common central process (Keele, Ivry, & Pokorny, 1987; Keele, Pokorny, Corcos, & Ivry, 1985; Studenka & Zelaznik, 2008; Zelaznik et al., 2005). According to this perspective, elite soccer players would be more proficient at anticipation timing than their novice counterparts regardless of the effector used. On the other hand, Ericsson et al.'s (1993) deliberate practice framework indicates that anticipation timing skill should be dependent upon the amount of practice accumulated with any given effector. According to this perspective, it would be expected that trained soccer players would be more proficient than novices only when using the feet. In addition, the more frequent use of the preferred foot by soccer players might reveal superior anticipation timing performance with the preferred foot than with the non-preferred foot.

The results supported two of the three accuracy-related hypotheses emerging from Ericsson et al.'s (1993) deliberate practice framework. For Novices, anticipation timing was found to be significantly more accurate (i.e., lower CE) with the hands than with the feet. This was likely due to the fact that many common activities require anticipation timing using the hands (e.g., shaking hands or reaching to receive a passed object) and so most individuals would have extensive experience with these effectors. For Experts, performance with the hands was similar to that with the feet. Taken together, these findings suggest that participants in the Expert group had improved their anticipation timing accuracy with the feet to a level that was comparable to that achieved with the hands while the participants in the Novice group had not. This increased accuracy was most likely due to the extensive training received by the Expert group involving object interception with the feet. Their history of soccer-specific training likely afforded experts the opportunity to improve the accuracy of anticipation timing required by passing, receiving, and shooting skills executed with their feet. These results did not support the hypothesis emerging from the notion that timed movements are controlled by a common central process. In addition mean scores indicated that Experts were more accurate than Novices with both preferred and non-preferred limbs. This difference was larger for the non-preferred limbs suggesting that the experience Experts had accumulated using non-preferred limbs translated into a performance benefit.

In contrast to the accuracy findings, results regarding the variability of anticipation timing responses (VE) suggested some support for the hypothesis that a common central process controls timed movements. The Expert group was significantly less variable in anticipation timing performance than the Novice group, suggesting that

consistency of anticipation timing performance may be dependent on a centrally controlled timing mechanism rather than effector-specific training.

Overall, the results of the present study suggest that variability in anticipation timing skill is influenced by a common central mechanism while accuracy is dependent upon effector-specific training. It is possible that the variability seen in anticipation timing performance is associated primarily with perceptual processes, which are common to all types of anticipation timing tasks, whereas accuracy is primarily associated with the effector that is responsible for the execution of the specific movement required in such tasks.

#### *Limitations*

The present study was limited in the following ways:

1. Anticipation timing scores for the Expert group may have been influenced by a tendency to intercept the ball as it arrives alongside the stepping foot (non-striking foot). The target lamp was situated in a position that ensured that only the specified limb was used to break the photocell beam. This position was slightly forward of the position in which a soccer ball would normally be intercepted. Hence, experienced players may have used previously learned movement procedures consistent with intercepting the light as it arrived alongside the stepping foot (non-striking foot) rather than at the actual position of the target lamp, which may have resulted in late bias in their anticipation timing performance.
2. The apparatus used to simulate the reception of a soccer pass was designed to be as close to a real experience as possible, however due to the constraints of the

apparatus, a gap between the laboratory setting and the real experience inevitably exists. As the Expert group is attuned to completing the action of receiving an actual soccer pass this may impact performance of the laboratory task when compared to the novice group that has no experience other than that of the experimental task during testing procedures.

3. The presence of a technical error in the timing software lead to the unsynchronized initiation of the Bassin Anticipation Timer and a secondary timing mechanism that was used to record reaction time and movement time for each trial. This lead to error in the reaction time and movement time data and resulted in the removal of the data from further analysis.

#### *Recommendations for Future Study*

Based on the present study the following recommendations for future research are offered.

1. Due to the unforeseen technological limitation in the collection of reaction time and movement time data, future research is warranted to examine these factors more closely. An investigation of reaction time and movement time in anticipation timing performance may shed light on the relative contributions of deliberate practice and central timing processes in the performance of anticipation timing tasks.
2. As evidence supporting both specific practice effects and a central timing mechanism was present in the findings of the current study, it is suggested that future research examine tasks consisting of both centrally controlled and specific components. Experiments designed to further explore the mechanisms and

factors that influence different aspects of anticipation timing tasks should examine both the perceptual and movement demands of the skill.

3. Future research should address the possibility of extending this experiment to a more ecologically valid field setting.
4. Future research examining limb preference and anticipation timing performance should be undertaken. Although no significant differences in either accuracy or consistency measures for preference were present, the group x preference interaction for CE barely failed significance.

### *Conclusions*

Based on the findings of the present study the following conclusions seem appropriate:

1. Due to effects of deliberate practice, the anticipation timing accuracy of experts with their feet closely matched that with their hands.
2. Expertise benefits are isolated in the foot, due to specific training effects received in soccer situations.
3. Due to a lack of specific training with the feet, novices were unable to perform as accurately with their feet as with their hands.
4. Experts were less variable than novices in anticipation timing performance, regardless of effector used.
5. Some aspects of anticipation timing performance skills are centrally controlled (variability), while others are subject to the effects of deliberate practice (accuracy).

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## APPENDICES

## Appendix A: Informed Consent

**APPENDIX A  
INFORMED CONSENT FORM**

**Anticipation Timing Performance as a Function of Experience and Effector-Specific Training**

You are invited to participate in a research study. The objective of this project is to investigate the extent to which anticipation timing performance is a function of effector-specific training. As a participant in this study you will be performing two simple motor skills. The tasks involve the interception of the apparent motion of a series of illuminated lights, in a manner that is similar to receiving a pass in soccer or hitting an approaching ball with your hand. There are no foreseeable risks associated with participation.

At the beginning of the experimental session, you will be given written instructions which the experimenter will also read aloud. During these instructions, you may ask questions whenever you like. You will be positioned on a wooden platform (4ft by 4ft) throughout the experimental session. Four limb conditions will be used: preferred foot, non-preferred foot, preferred hand, and non-preferred hand. You will be asked to complete 120 total trials, 30 in each limb condition. Within each condition 10 trials will be presented at each of three different speeds (4, 5, & 6 mph), presented in a randomly determined order.

The investigator will signal the beginning of each trial by indicating which hand or foot you are to use and then saying "ready". An amber warning light at the far end of the track-way will illuminate signaling the start of the light motion. The task will involve the presentation of a series of sequentially illuminated lamps to create apparent motion towards you. You will be required to step forward and break a photocell positioned over the target lamp with the instructed limb, at the exact time that the stimulus arrives at the target. Your performance scores will be recorded either directly by a computer system or by hand for entry into the computer system at a later time. Your participation will require approximately 1 hour to complete the experiment.

The information in the study records will be kept confidential. Data will be stored securely and will be made available only to persons conducting the study unless you specifically give permission in writing to do otherwise. No reference will be made in oral or written reports that could link you to the study.

If you have questions at any time about the study or the procedures, you may contact the researcher, Greg Young, at 1914 Andy holt Avenue, 144 HPER, Knoxville, TN 37996, or (865) 974-8768; or the researcher's graduate advisor, Dr. Jeffrey T. Fairbrother, at 1914 Andy Holt Avenue, 322 HPER, Knoxville, TN 37996, or (865) 974-3616. If you have any questions about your rights as a participant, contact the Research Compliance Services section of the Office of Research at (865) 974-3466.

**Your participation in this study is voluntary; you may decline to participate at any time without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed, your data will be returned or destroyed.**

**I have read the above information and agree to participate in this study. I have received a copy of this form.**

Participant's Name (print) \_\_\_\_\_

Participant's Signature \_\_\_\_\_

Date \_\_\_\_\_

**APPROVED**  
By *Brenda Lawson*

OCT 11 2007

Appendix B: Coach's Letter of Approval





## TENNESSEE SOCCER

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09/27/07

To Whom It May Concern,

This memo serves as permission for Greg Young to approach and acquire members of the University of Tennessee's women's soccer program for use in an experimental research study. I look forward to viewing the results once his study has been completed.

Sincerely,

A handwritten signature in black ink that reads 'Ange'.

Ange Kelly  
Head Coach  
Univ. of Tennessee

---

University of Tennessee  
117 Stokely Athletics Center  
Knoxville, TN 377996

Phone: (865) 974-4275  
Fax: (865) 974-8914  
Website: [www.utladyvols.com](http://www.utladyvols.com)

## Appendix C: IRB Approval



October 11, 2007

IRB#: 7431 B

TITLE: The Anticipation Timing Performance as a Function of Expertise and Effector-Specific Training

Young, Greg  
Exercise, Sport & Leisure Studies  
144 HPER Building  
Campus - 2700

Fairbrother, Jeffrey  
Exercise, Sport & Leisure Studies  
322 HPER Building  
Campus

Your project listed above was reviewed and has been granted IRB approval under Expedited review.

This approval is for a period ending one year from the date of this letter. Please make timely submission of renewal or prompt notification of project termination (see item #3 below).

Responsibilities of the investigator during the conduct of this project include the following:

1. To obtain prior approval from the Committee before instituting any changes in the project.
2. To retain signed consent forms from subjects for at least three years following completion of the project.
3. To submit a Form D to report changes in the project or to report termination at 12-month or less intervals.

The Committee wishes you every success in your research endeavor. This office will send you a renewal notice (Form R) prior to the anniversary or your approval date.

Sincerely,

Brenda Lawson  
Compliances

Enclosure

## Vita

Greg Young was born in Newcastle-Upon-Tyne, England, on July 25, 1983. He graduated from Willington Community High School in June, 2001. Greg attended Berry College in Rome, Georgia, where he received a Bachelor of Science degree in Health and Physical Education – Teacher Preparation in May, 2005. During his four years of undergraduate study, Greg was a member of Berry College’s Men’s Varsity Soccer team. While competing at the collegiate level, Greg served as a team captain and received All-America honors. Upon completion of his undergraduate degree, Greg returned to England to fill a position at his old high school. Realizing a desire to continue his education, Greg returned to the U.S.A. in pursuit of a graduate degree. His love of sports and his passion for working with athletes lead him to seek a degree in Sport Psychology.

In 2006, Greg entered graduate school at the University of Tennessee, Knoxville to study Sport Psychology. While completing his graduate degree, Greg taught undergraduate classes in the university’s Physical Education Activity Program. His endeavors as a Graduate Teaching Associate lead to his receiving the 2007 A. W. Hobt Memorial Award for excellence in teaching. In 2008, Greg will graduate with a Master of Science degree in Sports Studies with a concentration in Sport Psychology and continue his studies in the doctoral program in Sport Psychology at the University of Tennessee, Knoxville.