Anticipation-Coincidence Timing: A Constraint on Kicking Pattern

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Dedications

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Table of Contents

Chapter I

Introduction

Kinesiologists know the motor patterns for different attractor levels of fundamental skills but they know very little about what factors may change patterns as performers become more skilled. Kicking is one such fundamental skill that has well defined patterns but lacks information concerning why kicking patterns change. Kicking is characterized by a propulsive action in which the leg or foot is used to strike an object (Butterfield & Loovis, 1994). Research indicates that practicing kicking will result in a change in pattern (Anderson & Sidaway, 1994) but determining the variables responsible for such changes lacks empirical testing.

Kicking, throwing, and striking share similar dynamics in that each takes advantage of the open kinetic chain in order to increase the velocity of the most distal segment – the foot, the hand, or a striking implement. An open kinetic chain is a system of links with a fixed proximal base and an open distal end (Southard, 2002). The most massive segment is at the proximal (fixed) end and the least massive segment is at the distal (open) end. Rotation at the base of the fixed segment gives the system angular momentum. When the rotation of the proximal base slows down, the system attempts to conserve momentum by its transfer to the next distal segment. The less massive distal segment receives momentum from its proximal neighbor and consequently increases velocity. This transfer effect continues in sequence from proximal to distal segments until the most distal segment is the recipient of an increase in velocity. This transfer of velocity to the distal segment will not occur unless the distal segment is less massive than its proximal neighbor and the distal segment lags behind its proximal neighbor. Kinesiologists know that throwers (Southard, 2009) and strikers (Southard, 2003) may change motor patterns by scaling up on the velocity of performance and or altering the mass of limb segments. Since kicking shares the same dynamics it is logical to assume that increasing velocity of kick may result in a change in kicking pattern. The kicker's attractor level (skill level), can be defined by the number of segments that experience distal lag and a subsequent increase in distal velocity. Better performers will take full advantage of the open kinetic chain by maximizing distal lag and increasing the velocity of the distal segment at contact.

Based on distal lag there are four attractor levels for kicking. Attractor level one is when there is no distal lag of segments. The performer stands at the ball, brings the leg back, and rotates the entire leg forward as a single unit. Attractor level two is when there is lag of one distal segment. Typically, the performer will take steps toward the ball, the shank and foot together will lag behind the thigh at contact. At attractor level three there is lag in two distal segments, the thigh lags behind the trunk and the shank plus foot lags behind the thigh. Attractor level four is characterized by maximum distal lag. That is, the thigh lags behind the trunk, the shank lags behind the thigh, and the foot lags behind the shank. We can define attractor levels by the degree of distal lag. We assume that velocity of kick may change attractor levels but we know little of additional variables that may affect a change in motor pattern.

The dynamic systems perspective provides a basis for determining variables responsible for pattern change. This perspective is significantly different from traditional approaches to the control of movement. Typical traditional approaches do not address the physics of movement (e.g. joint reaction forces, moment of inertia, and gravity) and ignore neuronal processes such as the formation and use of synergies. Dynamic systems not only considers such variables but interprets their use in the explanation of motor control and motor coordination. The mover is viewed as a biological system with independent interacting subsystems (Davids, Button & Bennett, 2008). Subsystems include everything from individual cells to muscles and groups of muscles. The multiple component parts of each subsystem are called *degrees of freedom* (Bernstein, 1967*).* Numerous degrees of freedom allow individuals to accomplish movement goals in a number of different ways. A system with a single degree of freedom is constrained to behave the same way regardless of environmental changes.

The system's large number of degrees of freedom makes the choices for accomplishing a movement goal overwhelming if it were not for *self organization*. *Self organization* is when a system of individual parts comes together and its elements behave collectively in an ordered way (Shumway-Cook & Woollacott, 1995). Basically, this means that the movement system will self-determine execution of a movement based on the movement goal, the environment in which the movement is performed, and the performer's individual characteristics (Newell, 1986). In order to understand how a dynamic system is self organizing an understanding of the following basic terms is necessary. *Constraints* are individual, environmental or goal related variables that delimit choices for accomplishing a movement. Examples of constraints are gravity, body composition, psychological state, and instruction (Clark, 1997). Constraints may reach a critical value at which point they elicit pattern change and become *control parameters.* For example, when on a treadmill at a slow pace the performer utilizes a walking pattern, as velocity of the treadmill increases the walk changes to a jog and eventually a run. In this instance the control parameter for changing a walk to a jog and a jog to a run is velocity.

Control parameters are called non-essential variables because they are not related to the pattern of movement itself. It is important to realize that control parameters allow change in order to accomplish a movement goal. Sometimes that change does not favor a more efficient pattern. For example Southard, (1998) determined that an increase in mass of distal segments while throwing was a control parameter that decreased the use of the open kinetic chain thereby reducing the velocity of the hand. New patterns are organized by *order parameters*. *Order parameters* constrain or compress the degrees of freedom available to the elemental components (Thelen & Smith, 1994). Order parameters are oftentimes mechanical principles that the motor system can take advantage of in performing the movement. For example, the order parameter for walking would be the pendular action of the legs. The order parameter for throwing and likely order parameter for kicking is the open kinetic chain. When systems take advantage of these mechanical principles they self organize into motor patterns called *attractors*.

Research Question

Velocity of kicks is a likely control parameter that may instigate changes in motor pattern. The question for this study is what may be considered a constraint that may become a control parameters and change kicking patterns.

Hypotheses

It is hypothesized that: 1) kickers will change pattern when required to anticipate and intercept a moving ball at slow and fast velocities; and 2) pattern change will be differentially affected by skill level. That is, inexperienced kickers will demonstrate patterns further from mature (less distal lag) than experienced kickers.

Significance of the study

The importance of coordinating a kick relative to a moving ball has been overlooked in much of the scientific literature. We know there are differences in patterns for kicking a stationary ball compared to a moving ball (Egan, Verheul, & Savelsbergh, 2007). However, there are no studies that have directly examined the effects of anticipation-coincidence timing and change in kicking pattern. Anticipation-coincidence timing is visually tracking a moving object, predicting the time and place the object will arrive, and executing a response (kicking) that is coincident (Dunham & Glad, 1985). This study will add to our knowledge of constraints by examining potential changes in kicking patterns when anticipating the arrival of a ball to a location. It is important to determine the constraints related to skilled performance in order to understand the development of motor patterns and develop strategies for improvement of skill.

Chapter II

Review of Literature

This review will focus on two issues related to the research question. The first issue is anticipation-coincidence timing research. The second issue is research involving kicking pattern as a result of practice.

Anticipation-Coincidence Timing

Dunham and Glad (1985) examined the effects of velocity of a moving object and plane of motion on target accuracy. The apparatus was a roller-skate sized car with a 2 ¾ in. diameter Styrofoam ball located 8 inches above the car. The car was released to a 4-ft chute and then preceded to a 12 ft runway. Participants predicted the arrival of the ball to a flag at the end of the runway by depressing a pressure switch at the estimated time of arrival. Participants were tested at a fast velocity of 4.5mph (2.1 m/s) and a slow velocity of 3.6mph (1.61 m/s). Participants reacted to each velocity in both the frontal and sagittal planes. Scores were calculated as the difference between actual time of arrival and the time of pressure switch depression. Results indicated that anticipatory performance decreased in accuracy as velocity increased. In addition, it was determined that performance at a slow speed in the sagittal plane elicited the most error in anticipation-coincidence timing.

Ranganathan and Carlton (2007) studied the effects of visual cues on coincidence anticipation when striking an object. They examined baseball batters ability to distinguish between change-ups and fast balls in a virtual environment. Skilled and unskilled batters performed two conditions. For condition one they were instructed to verbally indicate the type of pitch (uncoupled), for condition two they were required to swing a bat to intercept the approaching (virtual) ball (coupled). A series of occlusions were used to force participants to visualize either the movement of the pitcher or the flight of the ball. They hypothesized that prediction accuracy would be greater for coupled than uncoupled responses when ball flight information was present. Results indicated that batters were significantly more accurate in predicting the type of pitch in the uncoupled response than the coupled response regardless of skill level or visual condition. They suggested that this occurred because swinging the bat to intercept the ball was a more difficult task. The skilled batters also displayed shorter swing times than novice batters. The delayed onset of swing allowed for the skilled performers to have increased viewing time. Results provided evidence that anticipation-coincidence accuracy of skilled batters was more dependent on visual information of the ball than movement patterns of the pitcher.

Ilmane and LaRue (2008) examined the effects of temporal pressures on anticipatory postural adjustments. They examined the posture of handball players while executing a throw. Participants were asked to perform handball throws with maximal force and velocity to reach a visual target board. Participants were required to maintain a stable posture on a force platform while throwing. Participants threw in three conditions, a reactive condition (initiating a throw as soon as a stimulus is seen), an anticipation-coincidence condition (synchronizing a throw with a timed target), and a self-initiated condition (a self-paced throw). Results indicated that there was larger variability in behavior during the anticipation-coincidence condition. Variability in the time constraints of anticipatory postural adjustments indicated that different strategies or preparatory processes were used during the anticipation condition.

Jackson and Morgan (2007) examined anticipation accuracy for novice, intermediate and skilled tennis players reacting to tennis serves. Participants were required to respond to a video serve presented in five conditions. The conditions were; no occlusion, ball occlusion, servers arm and racquet occlusion, leg and hip occlusion, and whole body occlusion. Participants physically and verbally indicated serve direction based on the video as well as indicating the confidence level in their choice (Jackson & Mogan, 2007). Results indicated that the skilled group's performance dropped the most during ball occlusion and arm + racquet occlusion conditions. The data indicated that skilled performers were affected most by occlusion of key variables needed for accurate anticipation-coincidence timing. Intermediate and novice performers initially had the lowest prediction rates. Their rates did not significantly change based on occlusion condition.

Visual search behavior in anticipation-coincidence timing tasks was examined by Savelsbergh, Williams, Kamp and Ward (2002). They determined a soccer goalkeepers' ability to accurately anticipate a soccer penalty kick. Participants used a joystick to anticipate the direction of a penalty kick (kick was projected to a screen). Predictions for correct height, side, and penalties saved were dependent measures. The results indicated that the expert goalkeepers performed better on the anticipation test than novice goalkeepers. The expert goal keepers also initiated the movement later than the novices relative to ball contact. They concluded that performers with anticipation-coincidence timing experience can more accurately predict time related tasks.

Egan, Verheul and Savelsbergh (2007) examined the coordination and accuracy of soccer kicks. Their study focused on the differences in coordination and timing accuracy of novice kickers and skilled kickers performing a stationary kick and a kick with a ball moving at a velocity of 3m/s. Their dependent measures were; timing to maximum hip angle of the kicking leg, timing to maximum hip angle relative to minimum knee angle, timing of minimum knee angle relative to ball contact and the timing of maximum velocity of the hip relative to ball contact. They hypothesized that a more skilled performer would have greater variability at their proximal limbs to compensate for degrees of freedom and controlling the most distal segment. The results of the study indicated that the participants with more experience were better at anticipation in the moving ball condition, and that the inexperienced kickers scored higher on accuracy in the stationary condition than the moving condition. There were no main effects by group for hip range of movement. The average time of the forward swing of the kick was shorter for experienced kickers. The differences within groups between the moving ball and stationary ball indicated that ball speed effected accuracy. The primary differences between, Egan et. als (2007) study and the present study are: 1) angle of ball release; 2) velocity at which ball was kicked; and 3) dependent measures relating to pattern change.

In summary, past research on anticipation-coincidence timing has determined that performance accuracy decreases of kicks increase (Dunham & Glad 1985), and anticipation-coincidence timing increases postural variability, which may indicate different coordination strategies for movements (Ilmane & LaRue, 2008). In addition, past research also indicates that performers with more experience show greater anticipation accuracy than inexperienced performers (Salvesberg, et al. 2002; Egan, et al. 2007)

Kicking Pattern Change

Past research has concluded that an efficient kicking pattern is one that proceeds in a proximal to distal sequence (Putnam, 1991). Davids, Lees, and Burwitz (2000) defined a mature kicking pattern as one that requires the performer to assemble a coordination pattern which facilitates the development of high velocities in the distal segment. Within this context the pattern used is a proximal-distal temporal sequencing. For a kick, the temporal sequencing would begin at the trunk and end at the foot. The Davids et al. (2000) and Putnam (1991) data indicate that pattern change to a more mature pattern or a less mature pattern would require an appropriate change in distal lag.

Anderson and Sidaway (1994) examined the effects of practice on motor coordination for mature kickers. The researchers hypothesized that constraints on the range of motion at the hip and knee would be lifted as a result of practice resulting in a more effective pattern of coordination. Participants were six college aged novice kickers. Data were collected before and after a 10-week practice period. The researchers identified segments by placing light reflective markers on the shoulder joint, hip joint, knee joint, ankle joint, and the fifth toe. Dependent measures were changes in joint and segment velocities, changes in timing relationships between joints and segments, and changes in range of motion at the hip and knee. Results indicated that after practice the amount of knee flexion prior to hip flexion increased and continued as the hip flexed forward. There was also an increase in maximum knee angular velocity and maximum foot linear velocity that was accompanied by less time between maximum velocities across segments. The changes indicated a release of degrees of freedom allowing performers to take advantage of the open kinetic chain.

Ball (2008) examined kicking pattern as it relates to maximal kick distance. His goal was to identify key technical aspects of distance kicking. Angular velocity of the knee, foot speed, and step lengths for different kicking distances were examined. He found that longer kick distances were associated with greater foot speeds, greater shank angular velocity, and longer steps before contact. Results also indicated different kicking strategies employed by participants. Some players used a thigh strategy (more thigh angular velocity with less knee velocity) and others were just the opposite by utilizing more knee angular velocity with less thigh angular velocity. The results indicated variability in kicking pattern across individual performers.

Kinematic characteristics of an instep soccer kick were examined for experienced and inexperienced kickers (Shan & Westerhoff, 2005). Participants kicked in two conditions, a run-up kick and a kick step. Three-dimensional motion analysis was used to determine relationships between angular velocities for joints. Results indicated that the whip-like activity representing a proximal to distal sequence of movement was more evident with the experienced performers. Unlike a previous study (Dorge, Bull-Andersen, Sorenson, & Simonsen, 2002) Shan and Weasterhoff (2005) found that the ankle joint was stable (locked) during the whip-like motion of the leg. The differences between the two studies suggest that foot lag may be variable depending on the circumstances of performance.

In summary, research on kicking pattern indicates that measurements such as hip and knee flexion, angular velocity and the segment of joint activity may be variable based on kicking condition (Anderson & Sideaway, 1994; Ball, 2008; Shan & Westerhoff, 2005). The results emphasize the possibility of multiple constraints that may differentially affect kicking pattern.

Chapter III

Methods

Participants

Participants were 20 university students (7 males and 13 females, ages 19-24 years). Participants were volunteers recruited by word of mouth from the Texas Christian University student population. Each participant was required to sign a university approved consent form prior to participation. Participants were selected based on their experience at kicking. One-half were experienced and one-half were inexperienced. Experienced kickers were defined as those with previous competitive soccer experience (high school varsity or higher). Inexperienced kickers were defined by those without any previous soccer experience. All participants were at least attractor level 3 kickers.

Apparatus

Data were collected with a PEAK Motus Motion Analysis System. Video cameras with a field rate of 60 Hz and a shutter speed of 1/8000sec were placed perpendicular to the principal plane of motion and directly behind participants in order to obtain 3-dimensional data. Video data were digitized using commercialized software provided by PEAK. Ball velocity prior to contact was controlled using a ramp. The angle at which the ball approached the kicker was 45 degrees to the direction of kick. To attain a slow velocity of 1m/s the ball was rolled down a ramp at an angle of 3˚. To attain a fast velocity of 3m/s the ball was rolled down a 1m ramp at an angle of 27.3°. Ramp angle was calculated using the formula $V^2 = 2(\text{Sin ramp angle})(A)(S)$. Where V = velocity of ball, sin ramp angle= sin of angle of incline, A = acceleration due to gravity 9.81m/s-^{2}, and S = length of ramp (1m). Therefore Ramp Angle = ArcSin (.5) $(V^2)/A \times S$. The ramp was not visible to the participant due to a 1.2 m wide and 2 m high screen placed between the participant and the ramp. A 30.5cm opening at the bottom center of the screen allowed the ball to exit. Opaque paper strips prevented participants from seeing the ball prior to its exit from the opening. See Figures 1, 2 and 3 for a representation of the ramp, screen, and experimental layout respectively.

Procedure

In order to determine movement initiation and kicking pattern light reflective markers were placed on the seventh spine of the cervical vertebra (C7), the temple of the head, greater trochanter of the femur (GT), the lateral epicondyle of the femur (LE), the distal apex of the lateral maleolus (LM), and the dorsal aspect of the fifth metatarsal head on the foot (FM). The first marker to move was used to determine timing of movement initiation (TMI) relative to ball position. Markers on the cervical vertebrae, iliac spine, epicondyle of femur, maleolus, calcaneus, and fifth metatarsal were used to determine segmental lag. Calculation of segmental lag was analyzed by subtracting the time to peak velocity (TTPV) of the proximal marker from its distal neighbor. Thigh lag was determined by TTPV of LE – TTPV of GT, shank lag was TTPV of LM – TTPV of LE and foot lag was TTPV of FM – TTPV of LM. Peak velocity of each of the markers was determined through examination of trajectory graphs. A positive value for segmental lag indicated that the distal segment lagged behind its proximal neighbor. A negative value for segmental lag indicated that the distal segment reached peak velocity before its proximal neighbor. Anticipation accuracy was measured by determining the timing of the ball at contact relative to a predetermined location (3.2m from the front of the ramp to the participant). A negative value indicated that the participant made contact before the marked point and a positive value indicated that the participant made contact after the designated location.

Digitizing of markers for patterns of kicks began with movement instigation and ended when the last segment reached peak velocity.

Participants were required to kick a regulation soccer ball in five conditions. General instruction for all conditions was to kick the ball as hard as possible (kick with maximum velocity). Participants were limited to two steps prior to kicking the ball. Conditions were categorized by anticipation condition and velocity of the ball prior to contact. There were no restrictions regarding the style of kick (toe or instep) utilized by participants. Condition 1 (C1, Stationary Ball) did not require anticipation-coincidence because participants kicked a stationary ball. Condition 2 (C2, Anticipation/Slow velocity) required anticipation-coincidence timing because participants kicked a ball moving with a velocity of 1m/s at a predetermined location. Condition 3, (C3, Anticipation/Fast Velocity) required an anticipatory-coincidence response because participants kicked a ball moving with a velocity of 3m/s at a predetermined location. Condition 4 (C4, No Anticipation/Slow Ball) did not require anticipation-coincidence because participants kicked a ball moving at 1m/s at a location determined by the participant. Condition 5 (C5, No Anticipation/Fast Ball) did not require anticipation-coincidence because participants kicked a ball moving at 3m/s at a location determined by the participant. Kicking accuracy (ball location following contact) was not a requirement for conditions; however, participants were encouraged to hit the 5X3 meter mat that was located 5 meters directly to their front.

Design and Analysis

Motor pattern change was determined by a 2-way MANOVA (5 Conditions X 2 Levels) for the three dependent measures of segmental lag (thigh-trunk, shank-thigh, and foot-shank). A significant MANOVA was followed by a 2-way ANOVA to determine dependent measures responsible for significance. A significant main effect or interaction was followed by Scheffe´

post hoc analyses to determine means responsible for significance. A Huyhn-Feldt adjustment was used as a correction for violation of sphericity. Partial Eta square determined effect size for the multivariate analyses.

Differences in anticipation accuracy were determined by a 2-way ANOVA (4 Conditions X 2 Levels). Although there are only two anticipation conditions, time from contact to the designated contact location was determined for all ball moving conditions to compare with the anticipation conditions. The dependent measures for anticipation were the time values (determined by trajectory graphs) of contact relative to the required location. Constant error for anticipation time was determined by contact before or after the designated location. Contact before the location was represented by a negative value and time after the designated location was represented as a positive value. Variable error time was a dependent measure representing the variability of constant error (positive and negative values). Absolute time (time relative to the designated location without reference to a positive or negative value) was also a dependent measure representing anticipation time. A significant ANOVA was followed by a Scheffe´ post hoc procedure to determine means responsible for significance by condition. The alpha level for all analyses was .05.

Chapter IV

Results

Pattern Change

Segmental lag. The results of the two-way MANOVA for dependent measures of segmental lag indicated significant main effects by Condition (Hoteling's T = .076), F (12, 3182)= 6.69, p<.01, ή² =.016; and Level (Hoteling's T = .082), F (3, 1062) = 29.146, p<.01, ή² = .075; with a significant Condition x Level interaction (Hoteling's T = .027), F(12, 3182) = 2.411, p< .05, ή² = .008. Follow-up ANOVA indicated that Thigh Lag (F (4, 1074) = 9.86, p<.01, ή² = .036) and Foot Lag (F (4,1074) = 9.29, p< .01, ή² = .001) were responsible for the significant main effect by condition. Thigh Lag (F (1, 1074) = 25.42, p<.01, ή² = .023), Shank Lag (F (1, 1074) = 45.68, p<.01, ή² = .041) and Foot Lag (F (1, 1074) = 11.52, p<.01, ή² = .003) were responsible for the main effect by Level and Foot Lag (F (4, 1074) = 4.42, p<.01, ή² = .011) was responsible for the significant interaction. The Huyhn-Feldt adjustment did not affect significance.

Thigh Lag. Post hoc analysis of main effect by condition indicated that the Stationary condition, Anticipation-Fast Velocity, and No Anticipation Fast Velocity conditions were greater than the Anticipation-Slow Velocity condition and the No Anticipation-Slow condition. Generally, the data indicate that fast velocity and stationary conditions favor an increase in Thigh Lag. The main effect by Level indicated that the Inexperienced performers had significantly greater thigh lag than the Experienced performers. It should be noted that although the Inexperienced performers displayed greater lag, both levels were consistently positive across conditions. See Figure 4 for a graphic representation of Thigh Lag by Condition and Level.

Shank Lag. The Inexperienced performers demonstrated greater Shank Lag than the Experienced performers. However, both levels of performers were consistently positive across conditions. See Figure 5 for a graphic representation of Shank Lag means by Level and Condition.

Foot Lag. Post hoc analysis of the Condition X Level interaction indicated significant differences in positive and negative foot lag by Condition and Level. Specifically, the Inexperienced performers experienced negative foot lag for all conditions with the Experienced performers experiencing negative foot lag for only the Stationary and Anticipation-Slow Velocity Conditions. While there were differences in the direction of lag for the No-Anticipation Fast Velocity Condition the differences were not significant by level of experience. See Figure 6 for a graphic representation of mean scores for Foot Lag by Condition and Level.

Anticipation

Constant Error. The two-way (Condition X Level) ANOVA for the dependent measure of Constant Error indicated a significant main effect by Condition ($F(3, 850) = 189.7$, $p < .01$, $R^2 = .888$). Post Hoc analyses indicated that the Anticipation-Fast condition was significantly greater than remaining conditions and the No-Anticipation Fast Velocity condition was greater than both Slow Anticipation conditions. The data indicate that the faster anticipation conditions produced greater positive constant error. Experienced and Inexperienced kickers had positive CE means for the Anticipation-Fast Velocity, and the No-Anticipation Fast Velocity conditions. Experienced and Inexperienced kickers had negative means for the Anticipation-Slow Velocity Conditions and the No-Anticipation Slow Velocity conditions. The positive means indicate that the Experienced and Inexperienced kickers made contact after the ball had passed the designated point in the Fast-Velocity Conditions. The negative means indicated that the Experienced and

Inexperienced kickers made contact before the ball arrived at the designated point for the Slow-Velocity Conditions. See Figure 7 for a graphic representation of Constant Error Means by Condition and Level.

Variable Error. The two-way (Condition X Level) ANOVA for variable error indicated no significant main effects or interactions indicating that conditions and levels displayed similar variability in constant error. See Figure 8 for a graphic representation of Variable Error Means by Condition and Level.

Absolute Error. The two -way (Condition X Level) ANOVA for Absolute Error indicated a significant main effect by Condition ($F(3, 850) = 4.61$, $p < .01$, $R^2 = .038$) and a significant Condition X Level interaction ($F(3, 850) = 3.18$, $p < .05$, $R^2 = .038$). Post-hoc analyses by Condition indicated that the No Anticipation Fast Velocity was most accurate with no significant differences between remaining conditions. Post hoc analyses of the significant interaction indicated that the Inexperienced performers were less accurate in the Anticipation Slow Velocity condition and the Experienced performers were less accurate in the No Anticipation Fast Condition. Mean scores by condition and level may be found in Figure 9.

Initial Movement to Contact. The two-way (Condition X Level) ANOVA for the time from Initial Movement to Contact (IMC) indicated a significant main effect by condition ($F(3, 850) = 18.68$, $p< .01$, $R^2 = .069$). Post-hoc analyses indicated that the fast conditions were significantly greater than the slow conditions with no significant difference between either pair of fast or slow conditions. See Figure 10 for mean times by level for Initial Movement to Contact by condition and level.

Ball Release to Initial Movement. The Two-Way ANOVA (Condition X Session) for time from Ball Release to Initial Movement (BRtoIM) indicated a significant main effect by condition ($F(3,850) = 289.39$, $p<.01$, $R^2 = .553$) and Level ($F(1,850) = 6.22$, $p <05$, $R^2= .553$). Post-hoc analyses indicated that time from ball release to movement initiation was greatest for the Anticipation Fast Velocity condition with both fast conditions greater than the slow conditions which were not significantly different. The Experienced performers had significantly greater times from BRtoIM than the Inexperienced performers. See Figure 11for a graph of BR to IM means by level and condition.

Chapter V

Discussion

The hypotheses that: 1) kickers will change pattern when required to anticipate and intercept a moving ball; and 2) pattern change will be differentially affected by experience level were both supported. The significant differences in Thigh and Shank Lag by condition, and Thigh and Shank Lag by level, did not indicate a pattern change because changes were on an absolute scale. That is, the amount of segmental lag was significantly different but there were no changes in the relative positions of such segments that would be indicated by differences in positive and negative lag values.

There is no research that has determined the ideal lag for kicking. Southard (2009) has identified optimal lag values for throwing which also utilizes the open kinetic chain. He determined that wrist lag is positive but decreases with an increase in skill level. In other words, more lag is not necessarily indicative of a better performer (Southard, 2009). Negative lag values indicate that the distal segment is reaching peak velocity before its proximal neighbor. Positive lag values indicate that the distal segment reaches peak velocity after its proximal neighbor. The point of optimal lag is unknown for kicking. Therefore it is unknown whether or not the greater Thigh and Shank Lag across conditions for the Inexperienced kickers indicates an improvement in pattern. It is logical to assume that the Experienced kickers were closer to a global pattern which would indicate that the greater lag values for the thigh and shank are indicative of a decrease in performance. Nonetheless, the significant condition x level interaction for Foot Lag supports pattern differences (differences in positive and negative values) by condition and level.

The order parameter for kicking is likely the open kinetic chain. Therefore, a change in attractor level for kicking is indicated by a change in the number of segments experiencing positive distal lag. The data indicate that the sequence of positive distal lag is proximal to distal. The foot was the only segment not to experience positive distal lag during the five conditions for both performance levels. The segmental lag data agree with Putnam's (1991) statement concerning the sequencing of segments for activities where the goal is to increase velocity of the most distal end of the open kinetic chain. Since the foot was the only segment to experience negative lag it becomes the most important element of the open kinetic chain for explaining possible coordination strategies. From a dynamic systems perspective it could be predicted that a system left to self-organize would utilize a coordinative structure that is most comfortable to the performer. Considering that all performers in this study are attractor level three, the finding that the thigh and shank lag were consistently positive was not a surprise.

If the Experienced performers were self-organizing their kicking pattern the expectation would be that the foot would also lag behind the shank. Inexperienced performers would not be expected to demonstrate a consistent foot lag. On the other hand, if the performer directs the muscular contraction indicating that the movement is not self organizing (Masters, Poolton, Maxwell, & Raab, 2008), the direction could interrupt the natural pattern of coordination (Kugler & Turvey, 1987) and the foot may not lag behind the shank for either level of experience. The idea that "hardwiring" or directing muscular contraction can disrupt the natural pattern of coordination is supported by Southard (2007). He found that when low level throwers concentrated on rotating their trunk while throwing, the hand did not lag behind the forearm after practicing for seven sessions. However, when performers received no instruction and allowed the pattern of movement to precede naturally the hand lagged behind the forearm following five sessions of practice.

In those instances where experienced performers demonstrate foot lag they may be self-organizing through the use of a coordinative structure. This could explain the positive values for the Anticipation-Fast, and No-Anticipation Fast Conditions. The idea is that in stationary and slower velocity conditions the performer has time to think about the kick and does not allow coordination to self-organize. However, the positive value for No Anticipation-Slow Velocity is contrary to a self-organizing explanation since experienced performers should again have time to "hardwire" the movement. The conclusion is that experienced performers utilize a coordination style that may be specific to condition. Such results support the findings of previous researchers examining kicking patterns that have concluded differential patterns specific to performer and conditions (Ball, 2008; Shan & Westerhoff, 2005). Note that the Inexperienced performers have consistent negative foot lag values across conditions. It is likely that there is an unknown variable, or variables, that have differential effects on the coordination strategy of experienced performers. The variance indicating change in positive and negative values for thigh lag and foot lag (See Figures 4 and 6) may be the result of different strategies utilized according to performer and condition.

Absolute error is a measure of anticipation accuracy without regard to the relative position of contact to the target location. That is, absolute error does not define whether contact was before or after the designated location. The absolute error data indicated that the Anticipation Slow-Velocity Condition and No-Anticipation Fast Velocity Conditions were responsible for the significant interaction. Initial Movement to Contact (IMC) data indicated significant differences in the preferred contact point (no-anticipation) for fast velocity with the

Inexperienced performers being closer to the designated point. The Experienced performers were closer to the designated point for the Anticipation-Slow Velocity condition which supports the general trend in anticipation data from this study that experienced performers are better at anticipating absolute accuracy for the slower conditions.

Constant error is a measure of accuracy relative to whether the performer contacts the ball before or after the designated point. Variable error indicates the consistency of performance for constant error. A large constant error with a small variable error would indicate that the performer was off the target but in a consistent location. On the other hand, a small constant error with a large variable error would indicate that the performer contacted the ball on either side of the target location. The constant error indicated that the fast conditions were positive for both levels of performers and the slow conditions were negative for both levels of performers. The constant error data was not surprising given that logic would dictate that the performers would tend contact the ball late in fast conditions and early for slow conditions. The expectation that experienced performers would have lower variability in constant error was not supported by the results since there were no main effects or interactions for variable error. The lack of difference in variability by experience is in agreement with the Egan et al. (2007) study.

Ball Release was marked at the point where the ball came through the screen. Initial Movement was measured by the first movement of any marker after Ball Release. Upon ball release, Initial Movement was initiated earlier in the Slow Velocity Conditions. This could be due to a default in measurement strategy. That is, participants would move a marker (e.g. head) independent of the initial movement to kick. In other words, participants consistently initiated movement, paused, then re-initiated movement to kick in the Slow Velocity conditions. In the Fast Velocity conditions, participants initiated movement and continued with their kick without the pause. Although participants initiated their kick earlier in the Slow Velocity condition, the total time of the kick, (Initial Movement to Contact) was shorter overall. The Fast Velocity conditions displayed the greatest IMC time indicating that they took longer strides and more time to kick the ball than in the slow velocity condition. The consistent pause noted in the slower velocity conditions could be further evidence of a hardwire strategy. Performers would not be expected to interrupt a self-organized movement. If the interpretation of hardwire and self-organizing movements is correct, this study indicates that self-organization and goal directed movements (hardwire movements) may occur at both experience levels of performance. The significantly less absolute error in the No-Anticipation Fast Velocity condition indicates that the point of interception was not a preferred point for either group. Apparently, anticipating to a non-preferred location or anticipating a slow velocity ball decreased anticipation accuracy.

From a practical standpoint, recognizing a coordinating strategy may dictate instructional strategies. If a directed, explicit movement is recognized as a coordinating strategy then a coach should encourage self-organizing in order to promote distal lag. Encouragement could be in the form of scaling up on a control parameter or in the focus of attention utilized by the performer. Wulf, Lauterbach, and Toole (1999) demonstrated that when performers focus on the goal of a task rather than specific limb segments both their performance and motor pattern are improved. They explained the improvement by stating that when performers concentrate on specific segments of the movement they do not allow the movement to progress naturally which restrains the performance. A dynamic interpretation of the data would be that concentrating on specific limb segments does not allow for self-organization.

In summary, results from this study indicate that anticipation time is not a control parameter that systematically changes kicking patterns for experienced and inexperienced high level kickers. It was concluded that coordination strategies utilized by performers are specific to the kicking condition.

Future research should attempt to determine the variables responsible for differential foot lag by anticipatory condition and experience of the kicker. Perhaps including younger lower level kickers will produce some systematic differences which could provide clues as to the variables that affect higher level kickers. Younger kickers would likely require less change in constraints in order to instigate a change in pattern (Thelen & Smith, 1994).

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Figure Captions

Figure 1. The ramp for obtaining consistent fast and slow velocities; see text for details.

Figure 2. The screen designed to prevent participants from viewing the ball during the roll down the ramp.

Figure 3. Relative position of participant, cameras, ramp, screen and data collection desk.

Figure 4. Mean Thigh lag by Level and Condition.

Figure 5. Mean Shank Lag by Level and Condition.

Figure 6. Mean Foot lag by Level and Condition.

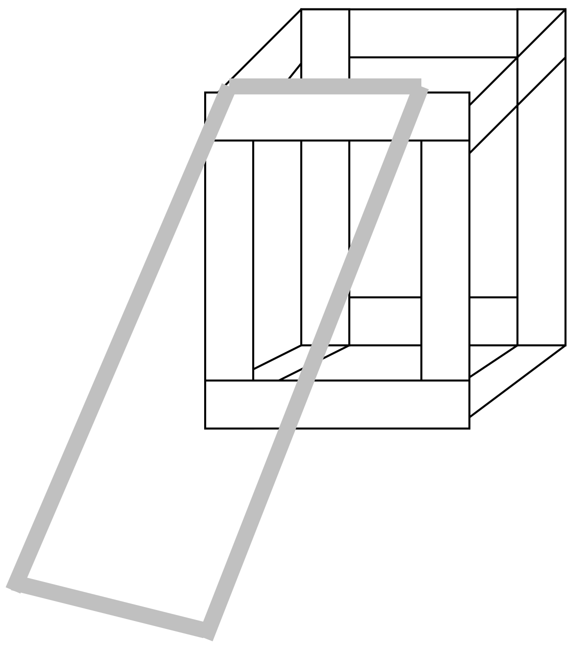
Figure 7. Mean values for Constant Error by Level and Condition.

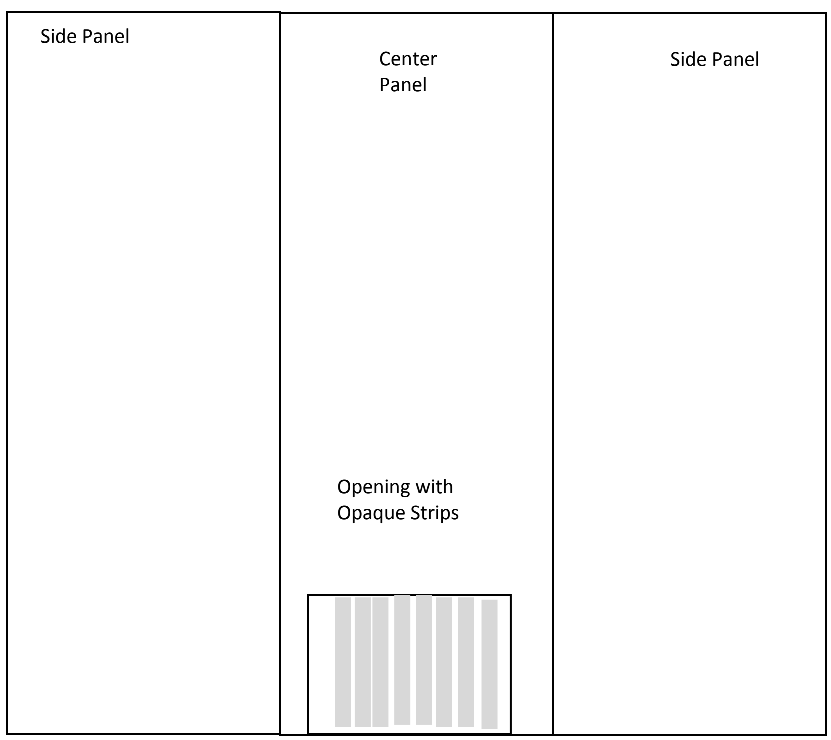
Figure 8. Mean values for Variable Error by Level and Condition.

Figure 9. Mean values for Absolute Error by Level and Condition.

Figure 10. Mean values for Initial Movement to Contact (IMC) by Level and Condition.

Figure 11. Mean values for Ball Release to Initial Movement (BRtoIM) by Level and Condition.

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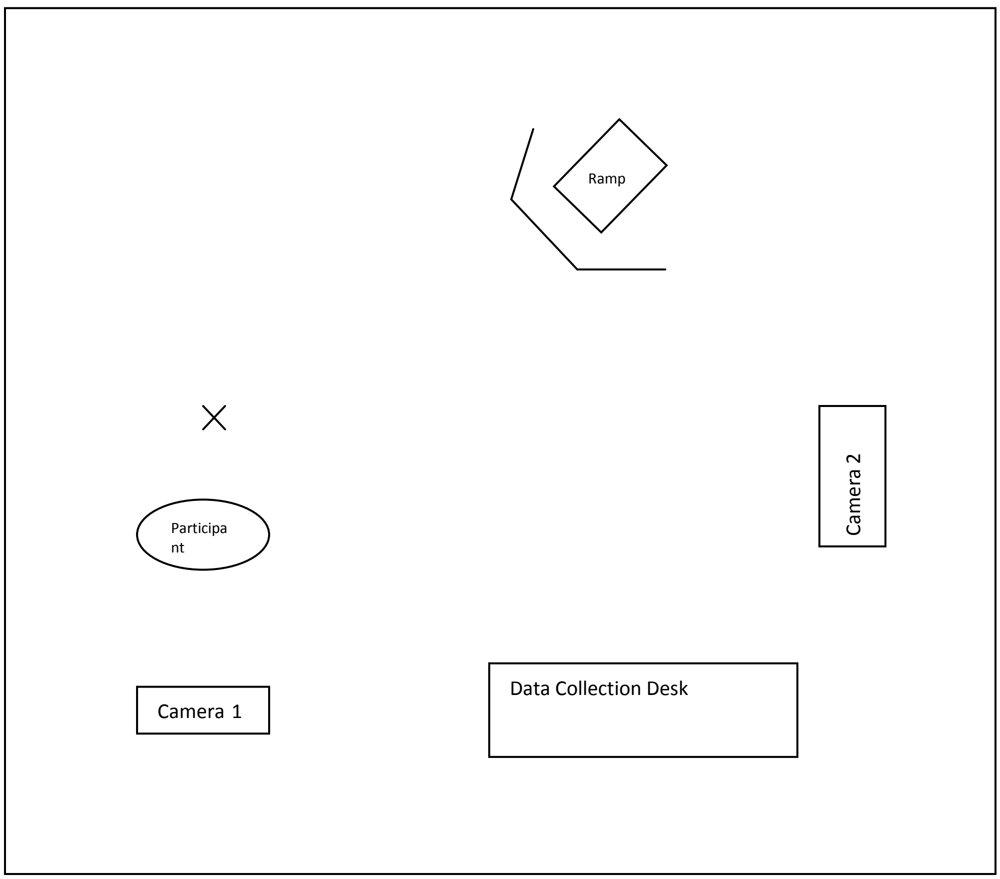
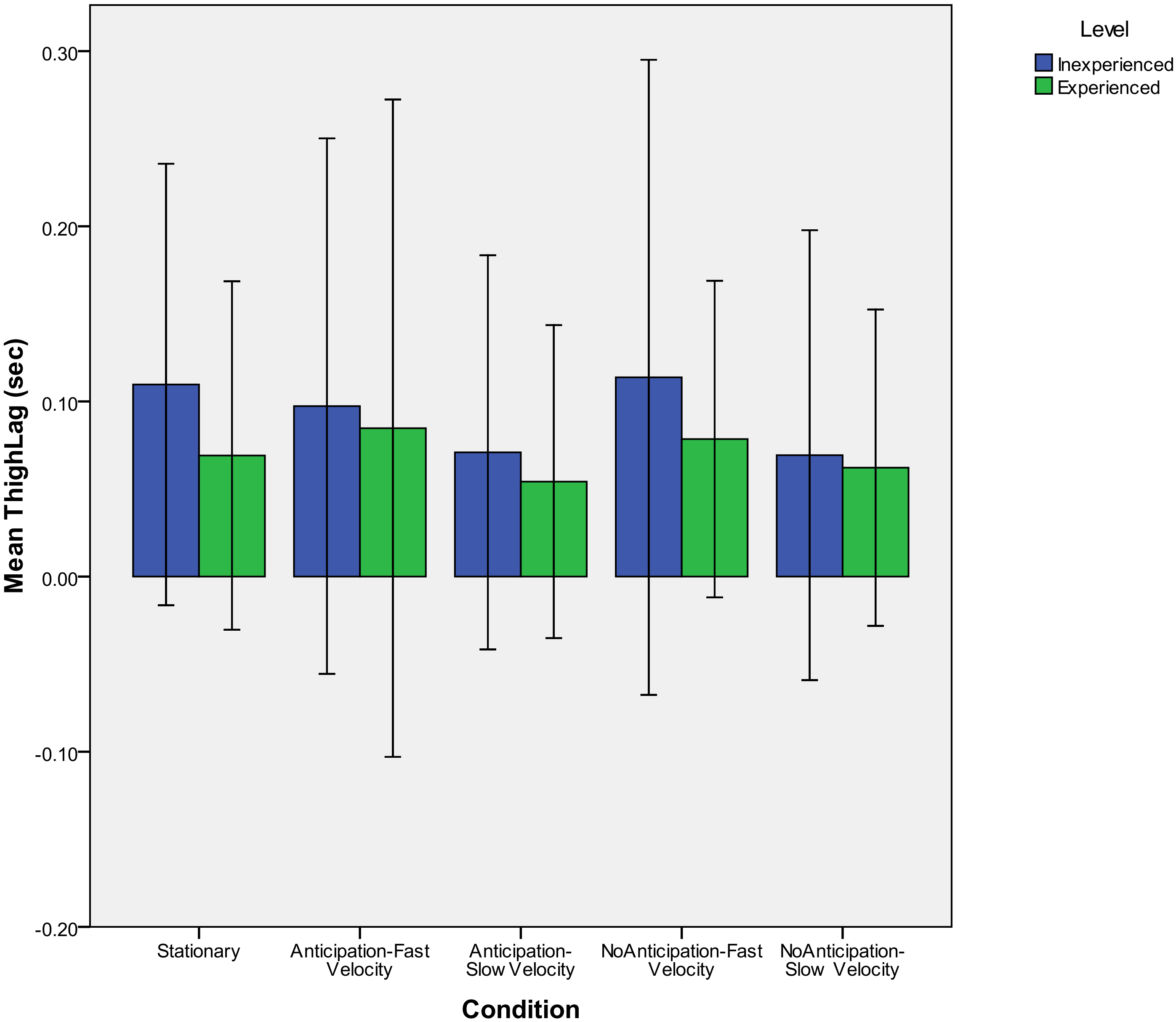
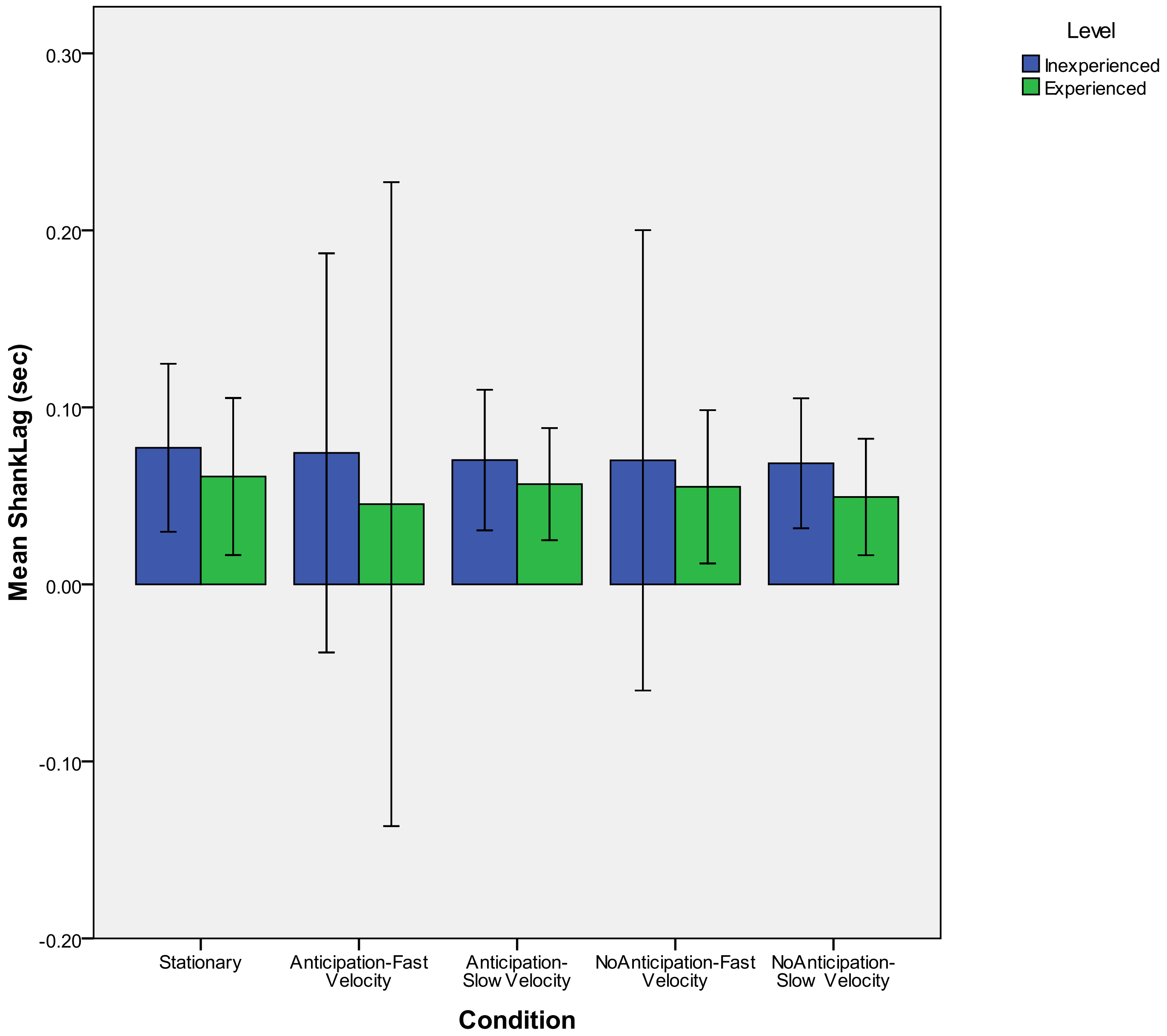
Center
Panel
Side Panel
Opening with
Opaque Strips

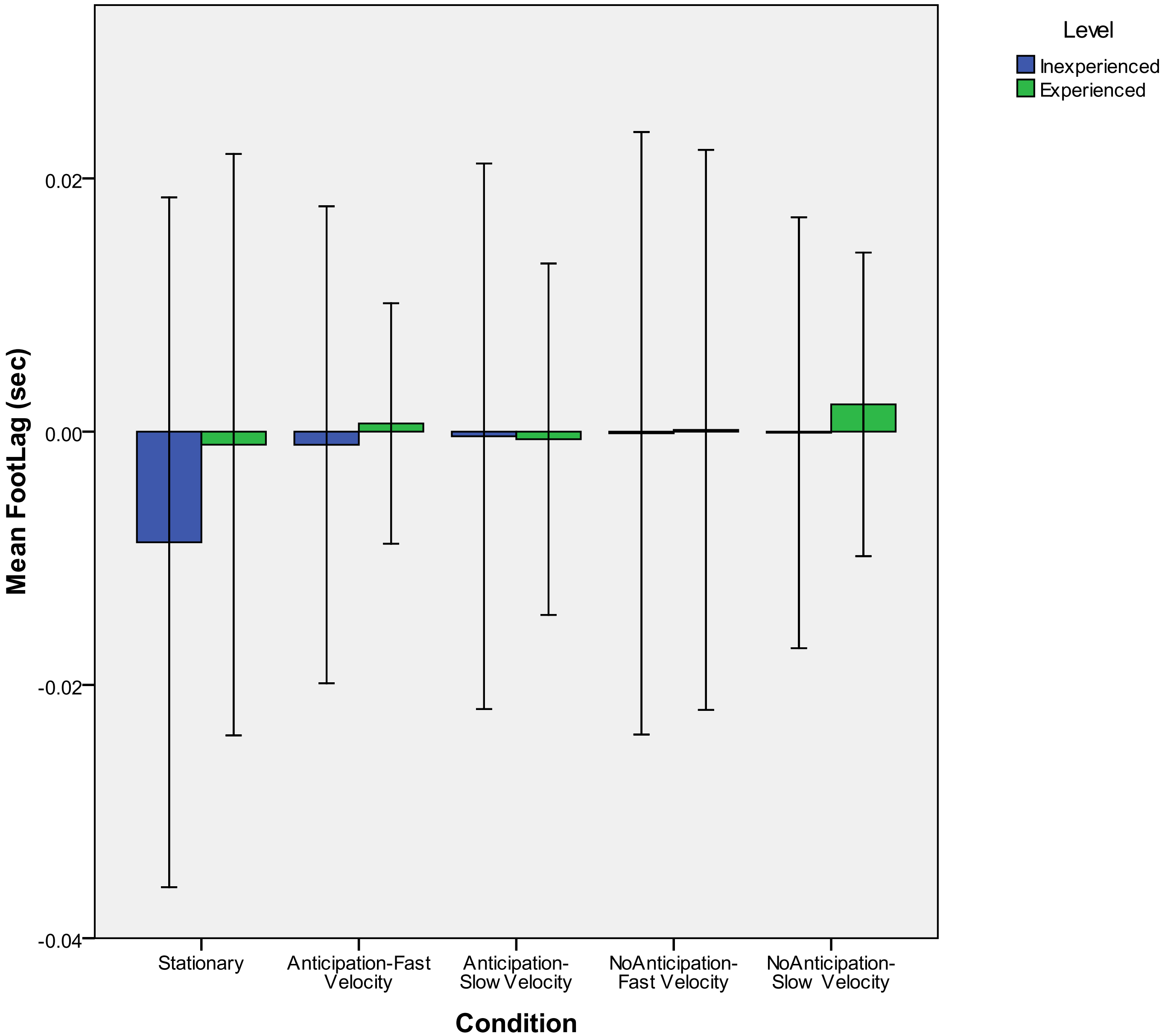

Ramp
Camera 2
Participa
nt
Camera 1
Data Collection Desk

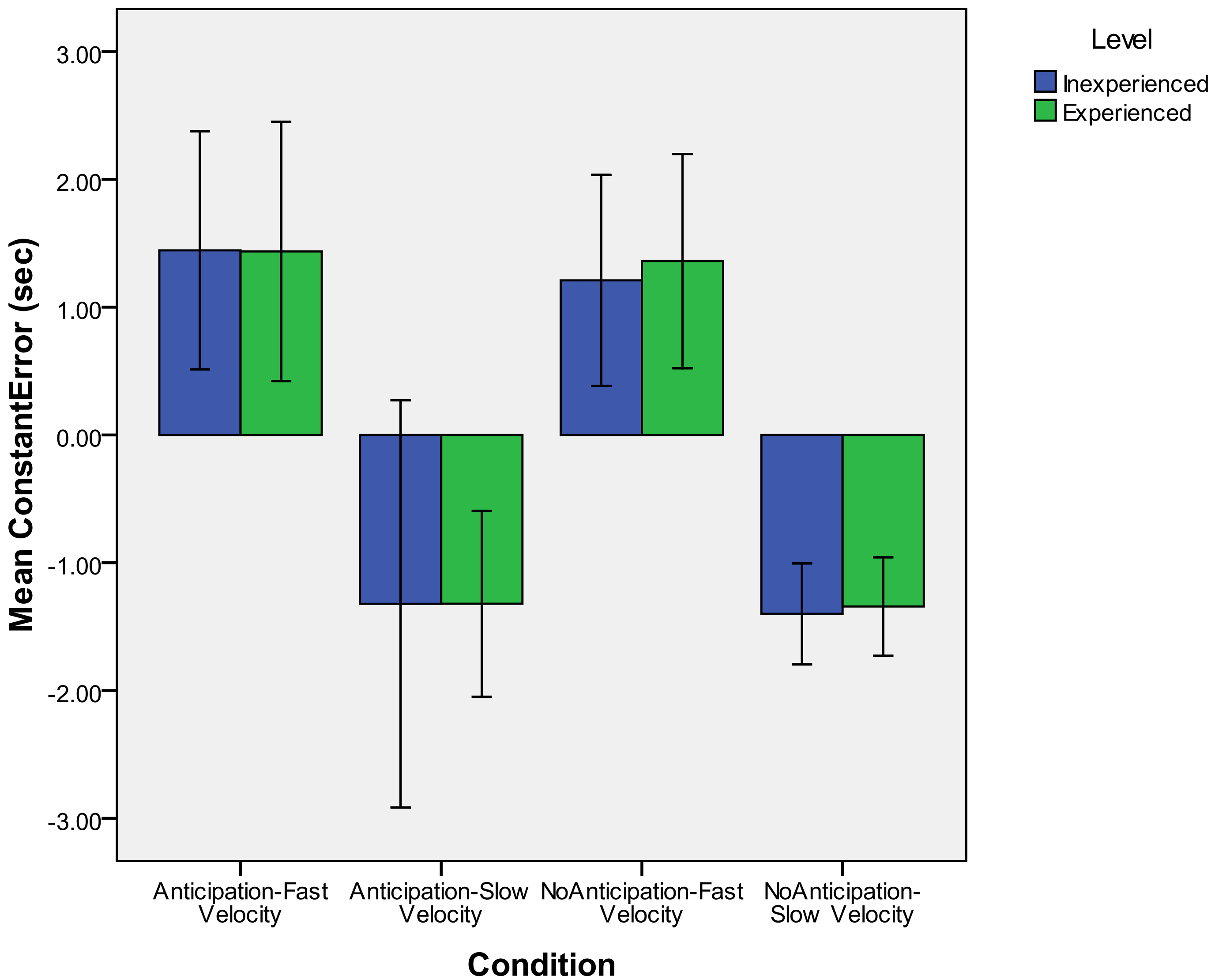


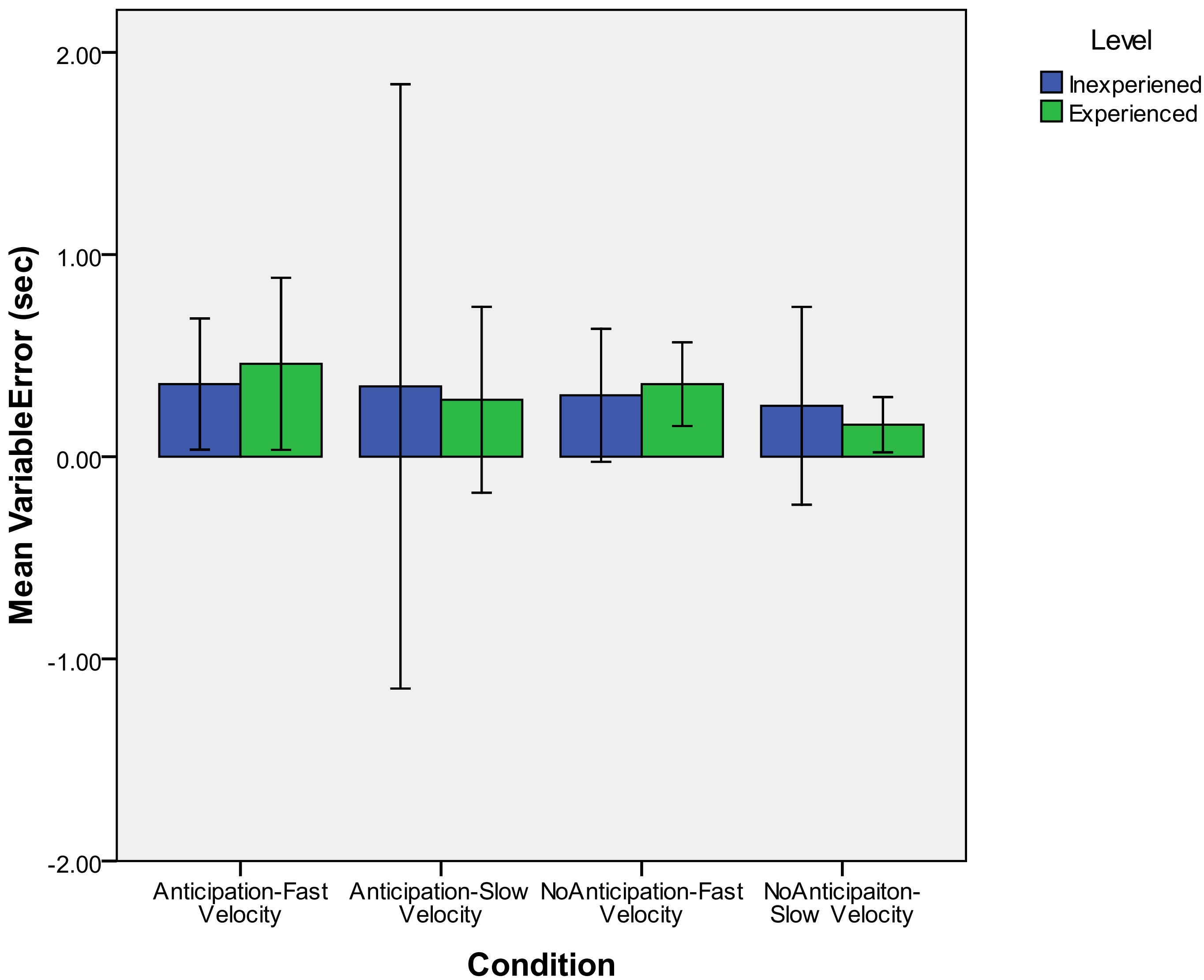
Level
Inexperienced
Experienced
Mean ThighLag (sec)
0.30
0.20
0.10
0.00
-0.10
-0.20
Stationary
Anticipation-Fast Velocity
Anticipation-Slow Velocity
NoAnticipation-Fast Velocity
NoAnticipation-Slow Velocity
Condition



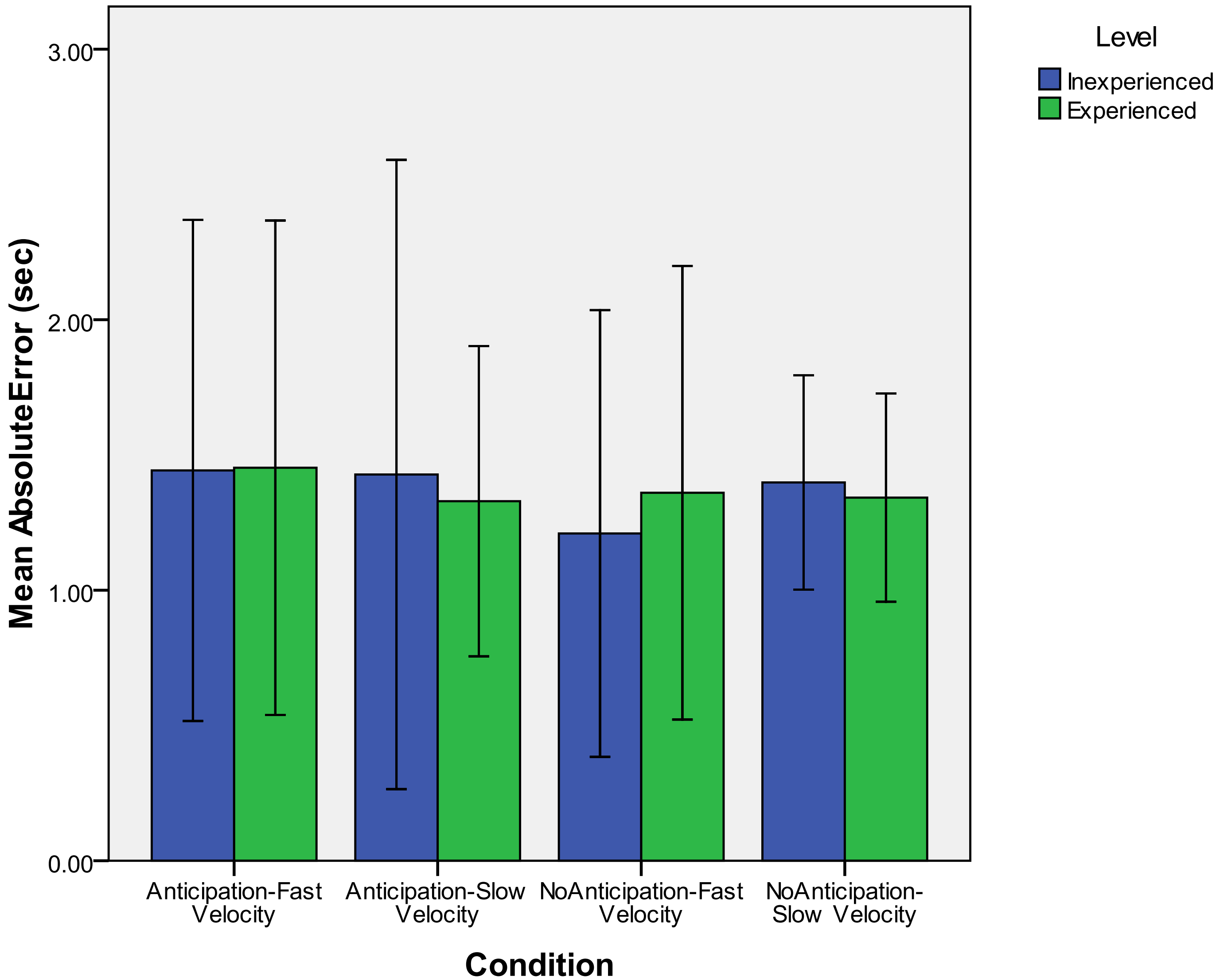
Level
Inexperienced
Experienced
Mean ShankLag (sec)
0.30
0.20
0.10
0.00
-0.10
-0.20
Stationary
Anticipation-Fast Velocity
Anticipation- Slow Velocity
NoAnticipation-Fast Velocity
NoAnticipation- Slow Velocity
Condition

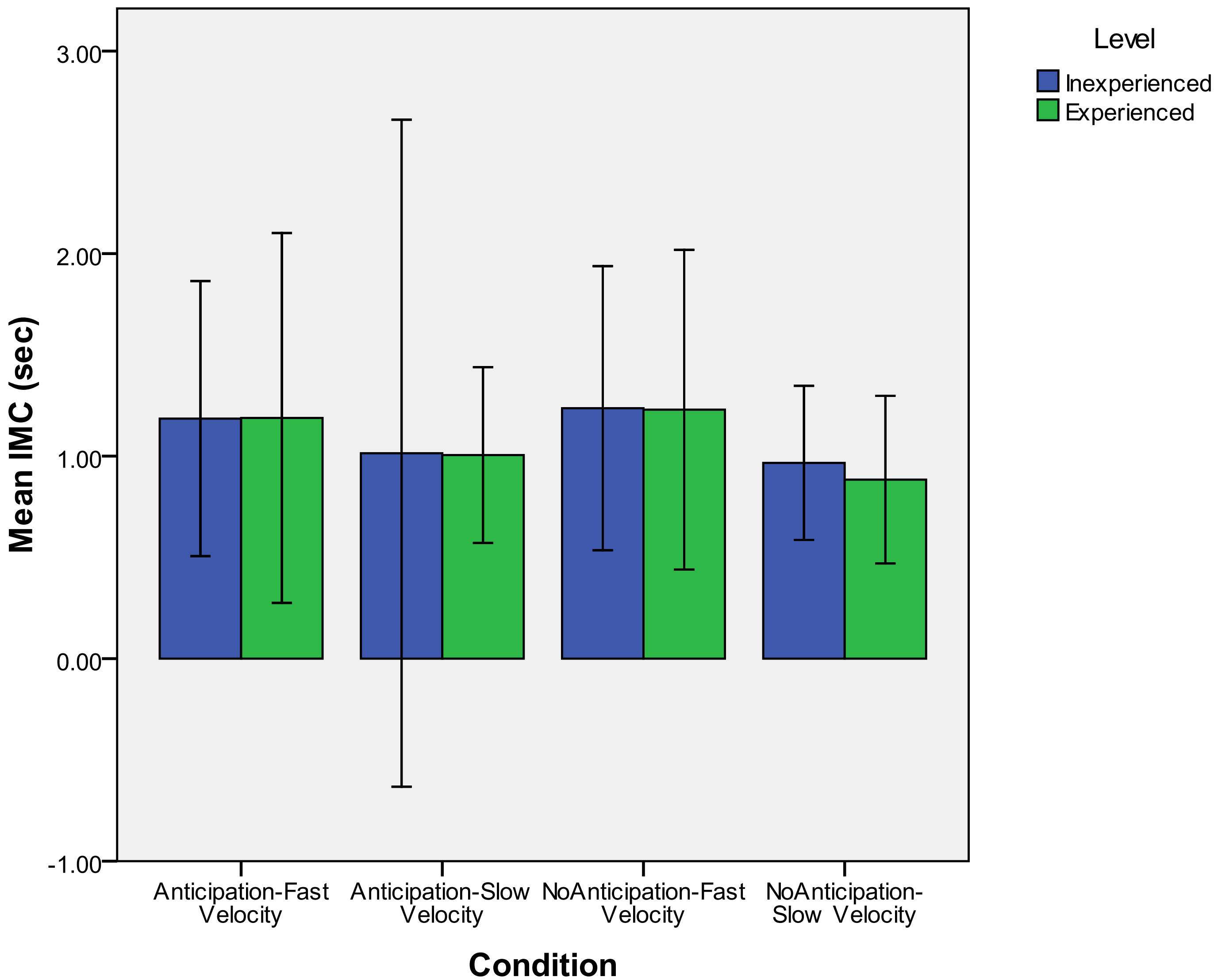

Level
Inexperienced
Experienced
0.02
0.00
-0.02
-0.04
Mean FootLag (sec)
Stationary
Anticipation-Fast Velocity
Anticipation-Slow Velocity
NoAnticipation-Fast Velocity
NoAnticipation-Slow Velocity
Condition

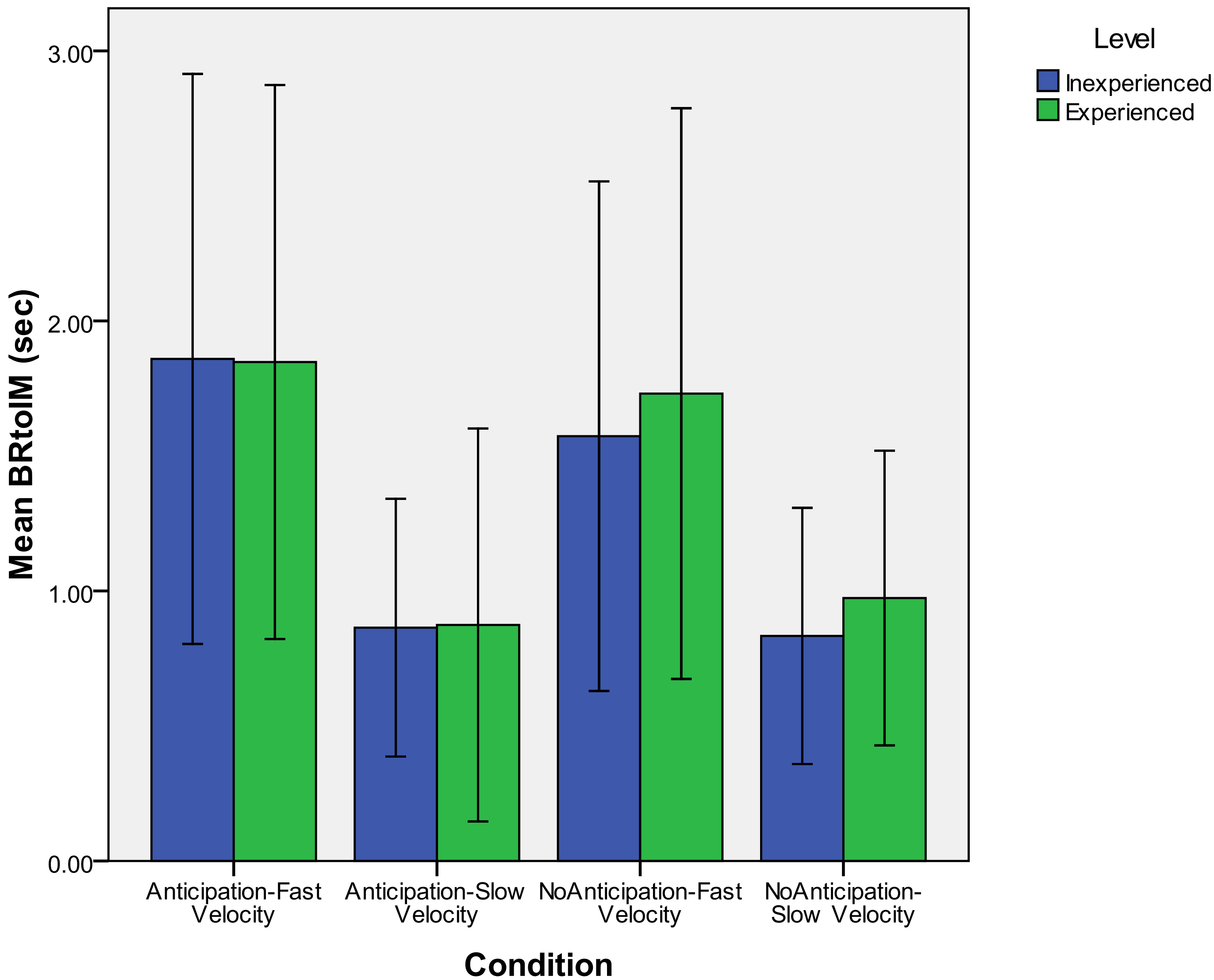

Level
Inexperienced
Experienced
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
Mean ConstantError (sec)
Anticipation-Fast Velocity
Anticipation-Slow Velocity
NoAnticipation-Fast Velocity
NoAnticipation-Slow Velocity
Condition



Level
Inexperiened
Experienced
2.00
1.00
0.00
-1.00
-2.00
Mean Variable Error (sec)
Anticipation-Fast Velocity
Anticipation-Slow Velocity
NoAnticipation-Fast Velocity
NoAnticipaiton-Slow Velocity
Condition


Level
Inexperienced
Experienced
3.00
2.00
1.00
0.00
Mean Absolute Error (sec)
Anticipation-Fast Velocity
Anticipation-Slow Velocity
NoAnticipation-Fast Velocity
NoAnticipation-Slow Velocity
Condition


Level
Inexperienced
Experienced
3.00
2.00
1.00
0.00
-1.00
Mean IMC (sec)
Anticipation-Fast Velocity
Anticipation-Slow Velocity
NoAnticipation-Fast Velocity
NoAnticipation- Slow Velocity
Condition


Level
Inexperienced
Experienced
Mean BRtoIM (sec)
3.00
2.00
1.00
0.00
Anticipation-Fast Velocity
Anticipation-Slow Velocity
NoAnticipation-Fast Velocity
NoAnticipation-Slow Velocity
Condition

Appendix A:

Consent Form

Texas Christian University
Fort Worth, Texas

CONSENT TO PARTICIPATE IN RESEARCH

Title of Research: Anticipation-Coincidence Timing: A Constraint on Kicking Pattern

Funding Agency/Sponsor: N/A

Study Investigators: Victoria Ramirez

What is the purpose of the research?
The purpose of this research is to determine if kicking a moving ball causes changes in kicking patterns. This information can help kinesiologists determine how skills develop and how to instruct motor skills.

How many people will participate in this study?
There will be approximately twenty participants in this study.

What is my involvement for participating in this study?
You will be asked to come into the motor behavior lab in the Rickel academic wing of the Rec Building for five sessions over three weeks. Each session will be on a different day and will take about 20 minutes. Your task for each session will be to kick a soccer ball that is stationary or moving at different velocities. Prior to kicking the ball harmless markers will be placed on your head, neck, knee, ankle and toe. The markers will reflect light that is picked up by video cameras and transferred to a computer for analysis. You will kick a total of 15 trials per session and each trial will be recorded on a video camera.

How long am I expected to be in this study for and how much of my time is required?
Each session is approximately 20 minutes. You will be expected to have five sessions over a three week period.

What are the risks of participating in this study and how will they be minimized?
The primary risks for the study are falling or straining your leg while kicking. This will be minimized by separating the kicking conditions over three weeks so that there are resting periods between conditions. You will also be required to warm-up by stretching prior to each session.

What are the benefits for participating in this study?
You will receive a mechanical analysis of your kicking pattern and learn about data collection for a mechanical analysis.

Will I be compensated for participating in this study?
There will be no monetary compensation for participating in this study. However, if you are a member of Dr. Southard's Biomechanics class you will receive extra credit points for your participation.

What is an alternate procedure(s) that I can choose instead of participating in this study?
If you are a member of Dr. Southard's class you may complete a review of 3 Biomechanics articles in lieu of participation in this experiment for extra credit.

How will my confidentiality be protected?
Only the investigators will be present during data collection. The lab will be closed and locked when sessions are in progress to ensure no interruptions and complete privacy. Recorded data will be password protected and stored on a secure computer so that only the listed investigators have access. Digitized information will not be saved with participant identifiers. Reported information will not be associated with any participant identifiers.

Is my participation voluntary?
Your participation is completely voluntary.

Can I stop taking part in this research?
You may withdraw from the study at any time without penalty.

What are the procedures for withdrawal?
The procedure for withdrawal from the study is notifying the principal investigator or supervising professor.

Will I be given a copy of the consent document to keep?
Yes, you will be given a copy of the consent form.

Who should I contact if I have questions regarding the study?
Should you have questions regarding the study you may contact the researcher Victoria Ramirez (817-797-3603) or the supervising professor Dr. Dan Southard (Phone 6869).

Who should I contact if I have concerns regarding my rights as a study participant?
Dr. Debbie Rhea, Associate Dean for Health Sciences & Research 817.257.6861 .

Your signature below indicates that you have been read the information provided above, you have received answers to all of your questions and have been told who to call if you have any more questions, you have freely decided to participate in this research, and you understand that you are not giving up any of your legal rights.

Participant Name (please print): ____

Participant's Signature: ____________________________________
Date:______________

Investigator's Signature: ___________________________________
Date:______________

ABSTRACT

Anticipation-Coincidence Timing: A Constraint on Kicking Pattern

By Victoria Ramirez, M.S. 2010

Department of Kinesiology

Texas Christian University

Thesis Advisor: Dan Southard, Ph.D

Kicking is a popular skill that has been the topic of multiple studies. However, little research has been done to identify control parameters that could potentially alter the pattern of kicking. The purpose of this study was to determine whether or not anticipation-coincidence timing is a constraint that affects kicking pattern through the examination of kinematic variables. Twenty participants (7 males, 13 females, age 19-24 years) performed 12 kicks at maximum velocity for 5 conditions. Conditions were categorized by required anticipatory response. Condition 1 (C1), Stationary Ball (no anticipation), Condition 2 (C2), Anticipation/Slow ball velocity, Condition 3, (C3), Anticipation/Fast ball velocity, Condition 4 (C4), No Anticipation/Slow ball velocity, Condition 5 (C5), No Anticipation/Fast ball velocity. Dependent measures for pattern change were thigh lag, shank lag, and foot lag. Dependent measures for anticipation were the time values of contact relative to the required location. Constant Error, Variable Error, Absolute Error, time from Initial Movement to Contact, and time from Ball Release to Initial Movement were dependent measures for anticipation. Three-dimensional data were collected with a Peak Motus Motion Analysis System. Segmental lag data were analyzed using a 2-way (Condition x Level) MANOVA. Significant MANOVA was followed by a two-way (Condition x Level) ANOVA to determine dependent measures responsible for significance. Scheffe´ post hoc procedure determined means responsible for significant differences. Dependent measures for anticipation were analyzed using a 2-way (Condition x Level) ANOVA. Analyses for pattern change indicated significant main effects for thigh, shank and foot lag. Foot lag was the only variable responsible for significant pattern change (indicated by differences in positive and negative values). Variability in foot lag throughout conditions indicated different strategies of coordination. Anticipation data indicated that both levels of experience consistently made contact before the designated point in the fast velocity conditions and after the designated contact point in the slow velocity conditions. Initial Movement was initiated faster in the slow velocity conditions and was interpreted as a hardwiring coordination strategy. Decreased error scores for C5 indicated that the point of interception was not preferred for either level of experience. Results indicate that anticipation-coincidence timing is not a control parameter for kicking. In addition, it was concluded that different coordination strategies may be used to elicit a kick based on individual conditions.