Changing Motor Patterns: Attentional Focus and Control Parameter

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CHAPTER ONE:
Introduction

The activity of overhand throwing is a universal motion that is displayed across cultures and continents. It appears as early as infancy and continues to be developed until adolescence and oftentimes into adulthood. The actual process of throwing is complex, with various components of the body working in unison to contribute to the execution of the movement. Teaching a throwing motion requires the combined knowledge of factors influencing pattern change and sound motor learning principles. Both areas are steeped in theory with opposing viewpoints regarding why patterns change as well as the use of instructional strategies.

A skill is defined as a task that has a specific goal to achieve while taking into account the mutuality of an organism and the skill environment (Newell, 1986; Magill, 2004). Skills are often described as being efficient, with the individual completing the task with minimal effort. A certain level of efficiency must be present, allowing the individual to accomplish the task with minimal effort while still maintaining maximal certainty (Clark, 1997). This suggests that a certain level of mastery is present, allowing the individual to achieve the goal in the most effective way possible. Skill can also refer to organisms behaving adaptively, with the individual adjusting to a changing environment. This interaction has impact on how the skill is executed. If the environment changes, the individual must be able to adjust and still accomplish the task at hand. The environment is an important aspect of the skill that is being performed. Different environments will provide different contexts to which the individual must adapt. Considering potential changes in the individual, the environment, the goal of the movement, and appropriate adaptations, it is a given that skill can not progress without pattern change.

The human body is a complex open system. An open system is a system where there is constant exchange of energy, matter, and information with the environment (Clark, 1997; Thelen & Smith, 1994). Exchanges with the environment potentially increase the complexity of movement and at the same time allow for adaptation (Thelen & Smith, 1994). Humans are able to adapt to a changing environment because of the large number of degrees of freedom in the human body. Degrees of freedom are the number of independent components of a system and all the ways these components can interact (Bernstein, 1967). The large number of degrees of freedom provides alternatives to the motor system but leaves the system a daunting task of selection. The most effective way to manage degrees of freedom and adapt to the environment has been a subject for debate by kinesiologists.

Traditionally, motor learning experts have examined the principles of transfer and augmented information as strategies to help the performer adapt to their environment, change motor patterns, and become more skilled. A recent approach regarding augmented information has been to examine the Focus of Attention of the performer. Focus of Attention can be "Internal" where specific body parts are emphasized in instruction or "External" where movement goals are emphasized (Wulf, 2007). Typically an instructor will observe the execution of a motor skill of interest and then attempt to improve the movement. This involves determining where changes can be made during the execution of the skill and then providing direction to the performer in terms of an Internal or External Focus of attention to facilitate such change.

Within the last ten years, the notion of Internal and External Focus of attention has received considerable examination. An Internal Focus of Attention commonly involves spatial awareness of specific body segments relative to other segments, the timing of the movement, and the order in which consecutive movements occur. An External Focus of Attention is where the performer is directed to focus on the effects that his or her movement has on the environment. It has been determined that, when an External Focus of Attention is adopted, an individual improves performance and retention of tasks better than when an Internal Focus is adopted (Wulf & Prinz, 2001). Improvement of performance and retention has been found to be applicable to a wide range of populations, motor skills, and skill levels when utilizing external focus (Wulf, 2007).

An alternative to more traditional learning strategies is related to Dynamical Systems Perspective. The alternative is called Ecological Task Analysis (ETA). Ecological Task Analysis has origins in adaptive physical activity. It was used primarily by adaptive physical educators because instruction to the performers required simplification compared to more traditional approaches. Nonetheless, the relevance of the approach in more traditional learning environments is rapidly increasing. Ecological Task Analysis indicates that the goal for a specific task must be expressed in constant intended outcomes instead of bodily segments (Davis & Burton, 1991). Instead of taking a movement and separating the individual components as more traditional instruction emphasizes, ETA suggests that performers should be informed of the task goal and be allowed to choose their movement form (Davis & Burton, 1991). The idea relates to the Dynamic Systems Perspective. A dynamic system is one whose elements change over time (Crutchfield et al., 1987). The human body is a dynamic system capable of self-organizing itself based on constraints related to the individual, the environment, and the goal of the movement. Self-organization allows individuals to make their own choices concerning motor outcomes, which is a central concept in ETA. Allowing choices in movement pattern minimizes the influence of verbal instruction and prevents the performer from being distracted from the goal of the task (Davis & Van Emmerik, 1995). It is crucial that guidance be offered in a way that allows the performer to choose his or her own pattern of movement without External influence. An effective way to accomplish this is by scaling up on a known control parameter.

A control parameter is a constraint on the system that, when scaled to a critical level, forces the system to change (Clark, 1997). Constraints provide behavioral boundaries for the system and allow the system to act in a certain way. When a control parameter is scaled to a critical value, the system becomes unstable. Instability of systems allows for change to accommodate the new movement constraints. Kelso and Schoner (1988) investigated change in patterns due to the scaling of a constraint. They required participants to flex and extend their index fingers together at a specific rate of speed. The participants were instructed to move their fingers at this speed while keeping them out of phase, that is, one finger was flexed while the other was extended. As the speed of finger movements was systematically increased, a critical speed was reached. This critical speed caused the fingers to suddenly switch to an in-phase pattern, where both were extended or flexed at the same time. The speed at which this change occurred was identified as the critical value. The critical value was the point at which the system spontaneously shifted from one stable attractor state to another. They concluded that motor patterns may change in specific ways without conscious instruction.

Despite the differences in the traditional and Dynamic Systems strategies, scaling up on a control parameter and External Focus have inherent similarities. Both strategies direct Focus on the goal or outcome of the task. An External Focus of Attention as well as scaling up on a control parameter (a common ETA strategy) allows for choices because the body is not constrained to act in a specified way. The explanation for the improvement in performance and retention that occurs when utilizing External Focus compared to Internal Focus is called the "Constrained Action Hypothesis" (Totsika & Wulf, 2003; Wulf, McNevin, & Shea 2001). The notion is that specific instruction overrides natural movement patterns and the automatic processes of the motor system are obstructed and the system progresses into disorder. Instructing performers to scale up on control parameters to instigate pattern change requires no instruction regarding pattern and should be even less constraining than External Focus instructions. The question that has not been investigated is whether an External Focus of Attention will change movement patterns as effectively as scaling up on a control parameter. The purpose of this study is to determine if scaling up on a control parameter serves to change motor patterns more effectively than providing the mover with an External Focus of Attention or Internal Focus of Attention. It is hypothesized that there will be no differences in motor pattern changes when providing the performer with an Internal Focus of Attention, an External Focus of Attention, or encouraging the performer to scale up on a control parameter.

CHAPTER TWO:
Literature Review

Focus of Attention

It has been suggested that where a performer directs their Focus of Attention has a significant effect on skill performance. Individuals commonly focus their attention either Internally or Externally. An External Focus of Attention is defined as focusing on goals or an implement or apparatus as opposed to focusing on specific body segments (Vance, Wulf, Tollner, McNevin, & Mercer, 2004; Wulf, 2007). When focusing internally, specific body segments receive attention by focusing on movement form, timing, and sequence of execution (Wulf, 2007). Research suggests that motor performance is more effective when performers adopt an External Focus of Attention instead of an Internal Focus of Attention. Totsika and Wulf (2003) required participants to complete a task of riding a Pedalo for a distance of seven meters while being timed. The Pedalo is a device that moves by pushing the upper platform forward and downward alternatively, similar to the pedals on a bicycle. Participants were assigned to an External Focus Condition or an Internal Focus Condition, with an equal number of participants in each condition. The Internal Focus participants were instructed to focus on pushing their feet forward, while the External Focus group was told to focus on pushing the platforms under each foot forward. Participants were instructed to proceed at a preferred pace. Transfer tests were done one day after practice. Transfer Test 1 involved riding the Pedalo forward as fast as possible, Transfer Test 2 involved riding the Pedalo as fast as possible backwards, and Transfer Test 3 involved riding the Pedalo forward under speed pressure while counting aloud backward in threes from a two-digit number given by the experimenter. Each transfer test consisted of four trials, with the novel characteristic among the tests being speed pressure. They found that the time needed to perform the task decreased across practice trials, with the External Focus group producing consistently faster movement times than the Internal Focus group. These results indicated that motor performance was more effective when performers had an External Focus of Attention while practicing the task compared to an Internal Focus of Attention. The higher level of performance was not only achieved faster but was retained more effectively.

Wulf, McConnel, Gartner, and Schwarz (2002) investigated the likelihood of learning and performance benefits resulting from feedback given in a more sport-specific setting. Forty-eight high school and university students were placed into two groups; a novice group and an advanced group. None of the novices had prior experience with the volleyball tennis serve, though all of the advanced players did have experience with the serve. Each participant was required to use the tennis-volleyball serve to the opposite court. In the middle of the opposite side of the court from the participant, a 3mx3m target was marked with 5cm-wide tape. A 4mx4m and 5mx5m area were marked around the target. If the center of the target was hit, then 4 points were awarded. Scores of 3, 2, or 1 were given if one of the three larger target areas or any other area on the side of the court was hit. Serves were performed from the right side of the court. Before beginning the first session, the experimenter spent several minutes describing basic techniques of the serve. Novices and advanced participants were assigned to either an

Internal or External Focus condition. For the Internal Focus group, the statements were: a) toss the ball high enough in front of the hitting arm, b) snap your wrist while hitting the ball to produce a forward rotation of the ball, c) shortly before hitting the ball, shift your weight from the back leg to the front leg, and d) arch your back and accelerate first the shoulder, then the upper arm, the lower arm, and finally your hand. Statements for the External Focus group were: a) toss the ball straight up, b) imagine holding a bowl in your hand and cupping the ball with it to produce a forward rotation of the ball, c) shortly before hitting the ball, shift your weight towards the target, and d) hit the ball as if using a whip, like a horseman driving horses. Each group was given one of four condition-specific statements after every fifth trial. The statement given was based on the part of the skill that needed the most movement. Each participant performed 25 practice trials in each of the two practice sessions which were separated by a week. One week after the second practice day, a retention test consisting of 15 trials was performed with no feedback provided during retention. They determined that External Focus resulted in a more effective performance when compared to Internal Focus with respect to accuracy for both the novice and advanced players. The type of focus received did not affect performance when given during practice, but it was found to have a permanent effect demonstrated by increased performance during the retention test. It was determined, based on the supplied focus statements and the resulting performance, that references to body segments do not need to be completely avoided as long as the Focus of Attention remains primarily External (Wulf, McConnel, Gartner, & Schwarz, 2002). Both novices and experts were able to better learn a movement based on an External Focus of Attention, suggesting that Focus of attention has learning generalizability to a wide population of skill levels.

Wulf, Shea, and Park (2001) examined whether the benefits of an External Focus of Attention are shared by all performers, or if there may be individual preferences for a specific Focus of Attention. They required seventeen undergraduate students to balance on a stabilometer. A stabilometer is a device consisting of a wooden platform that can shift to an inclination of 15 degrees on either side. Two orange markers were placed on the platform 18cm from the front edge and 25cm from the sagittal line. Participants placed the tip of each foot on the markers while remaining balanced for as long as possible during each 90-second trial. Half of the participants were instructed to begin the series of eight trials by focusing on their feet (Internal Focus), then switch to the markers (External Focus), and keep switching back and forth for each consecutive trial. The other half of the participants began the series of trials by Focusing on the markers (External Focus) then focusing on their feet (Internal Focus) for consecutive trials. It should be noted that the participants were instructed to look straight ahead and simply focus on their feet or the markers without looking at them directly. At the end of the first day of practice, participants reached a decision for their preferred attentional focus. Participants were reminded of their preferred attentional focus on the second practice day and were told to use this focus through the entire practice session. The second practice day also consisted of eight 90-second trials. On the third day, there were six 90-second retention trials. At the end of the retention tests, participants were interviewed to see whether they had used their preferred attentional focus during the retention of if they had focused on something else. Results indicated that participants were better able to perform the task across both days of practice, with no differences being present between the Internal and External Focus groups on the first two days. On the third day, significant group differences were present with twelve participants choosing an External Focus and only five choosing an Internal Focus. A significant advantage was found for those with an External Focus, suggesting that more practice allowed participants to realize that an External Focus provided better performance and learning (Wulf, Shea, & Park, 2001). When given the option of an Internal or External Focus of Attention, participants voluntarily chose an External Focus of Attention, implying that the benefits from an External Focus of Attention are not related to individual differences but instead are more general in nature. They concluded that benefits in performance can be experienced by a wide variety of people if an External Focus of Attention is adopted while learning a motor task.

It has been suggested that an External Focus provides greater learning and performance because the absence of specific direction allows the motor system to naturally select control processes governing movements (Wulf, McNevin, & Shea, 2001). This idea has been termed the Constrained Action Hypothesis. An External Focus of Attention lacks information specific to limb segments and theoretically allows control processes to proceed naturally. To test this hypothesis, Wulf, McNevin, and Shea (2001) conducted a study in which an Internal Focus of

Attention was compared to an External Focus of Attention. Twenty-eight students were required to balance on a stabilometer. The goal of the task was to keep the 65cm x 105 cm platform as horizontal as possible for as long as possible during 90-second trials. Two markers were placed on the platform as guidelines for foot placement. The markers were 9cm from the front edge and 23cm from the midline of the stabilometer. A secondary task was to press a hand-held response button as fast as possible when an auditory stimulus was given during the balance tasks. A computer recorded and stored the reaction time for initiation of auditory stimulus to depression of the button. Participants were randomly assigned to an Internal Focus condition or an External Focus condition. The Internal Focus condition required participants to look straight ahead while “focusing on their feet” and trying to stay horizontal. The External Focus group was instructed to look straight ahead while “focusing on markers’ attached to the platform. Auditory stimuli were given eight times during each of the six 90-second trials. All participants were told that the stabilometer task was the primary task and that the reaction time task was secondary in priority. A slower reaction time would be indicative of increased attention to the balance task. An increase in attention to the task would interfere with the ability of the motor system to naturally control the movement. Both groups demonstrated improved balance with practice, though the External Focus group had greater performance when compared to the Internal Focus group. The External Focus of Attention group also demonstrated increased frequency of responding and faster reaction times (decreased attention demands) relative to the Internal Focus of Attention group. It was concluded that an External Focus of

Attention allowed for a more effective and natural exchange between reflexive and voluntary control processes

More recent studies have examined efficiency of movement during Internal and External Focus by examining EMG (Vance, Wulf, Tollner, McNevin, & Mercer, 2004). Twelve male university students underwent a strength assessment of the right elbow-flexor muscles. Individual bilateral maximal force productions were then calculated, with 50% of this value being added to a curl bar. Participants were instructed to perform a biceps curl with their back to a wall to isolate the flexors of the arm. Two conditions were given; an Internal Focus of Attention, where the participants directly Focused on their biceps muscles, and an External Focus of Attention condition, where participants were instructed to concentrate on the curl bar. Participants performed two sets of ten repetitions per condition, for a total of forty repetitions. Half the participants performed the bicep curls in an Internal-External-Internal-External fashion, and the other half of the participants performed the bicep curls in an External-Internal-External-Internal fashion. A metronome required participants to perform their movements in sync with the clicks produced by the metronome every one and a half seconds. Results indicated that integrated EMG recording were less when movement were performed with External Focus when compared to an Internal Focus of Attention. This suggested that similar movements were performed with a greater movement economy, indicated by the lower neuromuscular activity. It was suggested that the External Focus condition had more effective recruitment of motor units, leading to a movement that was more effective and more efficient when compared to the Internal Focus of Attention condition.

Dynamic Systems

A dynamic system is described as an open, complex system that constantly adapts to its environment over time (Crutchfield, Farmer, Packard, & Shaw, 1987; Magill, 2004). Complex systems have a multitude of interacting components, with each component being sensitive to changes within the system and its environment. Such systems are faced with potential instability. Complex systems adapt to instability through self-organization. Self-organization is an identifying factor of a dynamic system and is indicative of a natural sequence for skill development (Southard, 2006). Motor patterns form naturally as a result of constraints on the system and the dynamics of the task itself (Southard, 2006). Newell (1986) suggested that constraints originate from three primary sources: the individual, the environment, and the goal of the task. Individual constraints are those occurring within the individual, including physical (such variations in musculature or skeletal segments) as well as psychological constraints (including memory or attention). Environmental constraints arise from changes in movement condition such as a larger, noisier crowd during a performance. If the goal changes, the pattern utilized to accomplish the goal may also change. For example, throwing to a target may require a different pattern than throwing without regard to accuracy.

A combination of factors may increase the complexity of the motor system and such factors must be organized if desired results are to ensue. The system becomes more complex as the number of movement possibilities increases.

Increasingly complex systems exhibit more degrees of freedom. The degrees of freedom in a system are defined as the number of independent elements or components and the number of ways each component can act (Bernstein, 1967). Constraints guide the system toward a solution to movement goals by reducing the number of possible movement patterns. Therefore, constraints serve to reduce the complexity of the motor system.

A control parameter is defined as a constraint that, when scaled to a critical level, brings about change in the system (Clark, 1997). As the control parameter is scaled to this critical value, a temporary period of instability is present in the system (Clark, 1997; Kelso, Scholz, & Schoner, 1986; Thelen & Smith, 1994). Instability is necessary for pattern change. It is important to realize that control parameters have no intent to change patterns of movement. In fact, they are non-essential variables relative to the pattern of movement. That is, control parameters are not part of the movement pattern itself. The more stable a system is, the greater change is required in control parameters to drive the system to instability and allow for change (Thelen & Smith, 1994). It follows then that from a Dynamic Systems Perspective, the key to changing motor patterns is to identify control parameters. However, this is difficult considering all the possible parameters that may affect the stability of a system. Southard (1998) determined that mass and velocity are two control parameters for overhand throwing. When mass and velocity were scaled to a critical level, motor patterns changed to a more mature pattern. Southard also determined critical values by identifying the percent of maximum velocity at which patterns changed (Southard, 2002). These critical values vary from segment to segment. For example, he found lower skilled throwers (Levels 1 and 2) typically show qualitative changes more often in the wrist and elbow joints compared to higher skilled throwers (Levels 3 and 4), who experience less changes because their patterns are more stable. Critical values occurred in the wrist joint at 40% and 90% of maximum velocity in Level 1 throwers and at 20% of maximum velocity in the elbow joint. For Level 2 throwers, critical values occurred at 10% and 90% of maximum velocity for the wrist joint and 10% maximum velocity in the elbow joint (Southard, 2002).

When patterns change, new patterns form according to an order parameter. Order parameters are variables that define the overall behavior of the system (Thelen & Smith, 1994). Order parameters set the boundaries in which a system is able to operate. These limitations ultimately serve to compress the degrees of freedom (Haken, 1977). This compression in the degrees of freedom enables the system to better organize and accomplish the task at hand. Order parameters are usually mechanical principles about which the system self-organizes. For instance, the order parameter for the overhand throw is the Open Kinetic Chain (Southard, 2002). That is, the arm is a system of links that has a fixed base and an open end. Movement of any segment in the link may affect all other segments. This enables the segments of the arm to maximize the transfer of angular momentum as the throwing motion progresses. The most massive segment, the trunk, is located at the fixed end of the kinetic chain. As the arm tapers in mass from the humerus to the hand, each distal segment is less massive that the proximal neighbor. When the larger proximal segment reaches peak velocity and subsequently slows down, it transfers angular momentum to the less massive distal neighbor. The result is an increase in velocity of the less massive segment. This transfer continues down the chain with the least massive segment (the hand) being the final recipient of velocity increases. Such velocity increases will not occur unless the distal segment lags behind the more massive proximal neighbor.

As a control parameter is scaled to critical levels, variability occurs in the system, causing the system to become unstable. The system self-organizes in order to adapt to the instability, and a new pattern of movement occurs, called an attractor state. Attractor states are determined by order parameters, and constitute the most efficient way of moving within the constraints on the system. For throwing, there have been four identified attractor states, based on how well the individual takes advantage of the Open Kinetic Chain (Southard, 2002). The least skilled, Level 1, exhibits arm and elbow extension with no lag between the segments of the arm. A Level 2 thrower shows lag of the hand relative to the forearm, but fails to display lag between the forearm and the humerus. Level 3 throwers display segmental lag of the forearm and the hand, but no lag of the humerus relative to the trunk. The most skilled level of throwers, Level 4, exhibit segmental lag of all the segments of the arm: the hand relative to the forearm, the forearm relative to the humerus, and the humerus relative to the trunk. As one becomes a more skilled thrower, he or she takes full advantage of the order parameter for throwing, the Open Kinetic Chain.

Dynamic Systems and Instruction

Traditionally, instructors have approached the task of motor learning by identifying individual parts of a skill and then ordering them for the performer from simple to complex (Herkowitz, 1978). The individual parts of the skill are then learned in a progressive fashion by the performer, ultimately contributing to learning the entire movement. The rationale behind this is that it is easier to learn simpler parts of a movement and then proceed to more difficult ones. When all parts of the skill are mastered, the performer is ready to proceed with the entire skill. The problem with this theory lies in the fact that oftentimes the task goals for separated parts of a skill are much different than the task goal for the overall skill itself (Burton & Davis, 1996). An inherent problem with this is the fact that the simplification of a complex skill does not equate to simpler tasks with individual goals (Davis & Burton, 1991). In addition, the environment that the skill is being performed is oftentimes not taken into account. Because each performer is a unique individual with a wide variety of constraints, a model template cannot be applied to everyone (Burton & Davis, 1996). Ecological Task Analysis is a relatively new way of approaching motor learning and is a distinct departure from previous task analysis strategy. Ecological Task Analysis (ETA) examines the dynamics of movement behavior by analyzing the various constraints including task constraints, individual constraints, and environmental constraints (Burton & Davis, 1996). Ecological Task Analysis involves several primary steps (Davis & Burton, 1991). The first step is to establish a goal for the task at hand. It is imperative that the goals of the task be clearly identified. To aid with this, environment along with verbal and other cues should be structured so the individual has a clear understanding of what is to be achieved. The second step is to provide the performer with choices as to how the task goal is to be achieved. This allows the body to act as an unrestricted dynamic system, putting to use the automatic, natural processes that control movement. The performer should practice the task, ultimately choosing the movement form that feels the most natural while achieving the task goal. Movement solutions from the instructor are discouraged, as they tend to be inflexible and do not allow the performer to naturally adapt to unforeseen changes. The use of the performer's own solutions to the problem posed by the specific task goal should be encouraged, ultimately promoting identification between the performers and the task they are attempting to accomplish. Third, the performer variables and relevant task dimensions should be identified. Control variables are identified and manipulated, causing the system to become unstable and forcing new patterns to be adopted in an attempt to bring the system back to stability. Ecological Task Analysis allows for the instructor to determine under what set of conditions the individual is able to achieve a task, the conditions that bring about the most efficient performance, the ability of the individual to apply solutions to the movement, and the consistency as these movement solutions are applied to similar movement problems (Davis & Burton, 1991). Ecological Task Analysis establishes goals for the task and emphasizes non-essential variables (control parameters) as an instructional strategy. An essential component of ETA is emphasizing a control parameter to instigate pattern change.

Control parameters and an External Focus of Attention have both been documented to effectively change motor patterns to better suit the environment in which a motor skill is being performed. Control parameters and External Focus of Attention (to varying degrees) would prevent the apparent disadvantage of unnatural skill development. By preventing the motor system from being externally constrained, the motor system is allowed to naturally select the most efficient motor pattern based on the goal of the task. The purpose of this study is to determine if Focus of Attention (External or Internal) is as effective as scaling up on a control parameter for changing a motor pattern. In addition, the study should determine if such changes result in a learning effect.

CHAPTER THREE:
Methods

Participants

Participants were forty-one university students, ages 18-24. There were no gender restrictions for this study. All participants were right-hand dominant with no physical limitations. Participants were recruited from the general student body by word of mouth and email. Before participating, each person signed a university-approved consent form.

Apparatus

A Vicon Motus 9.2 Peak Motion Analysis System was used to collect and digitize data. The system employs two digital cameras. One camera was placed 5 meters directly behind the participant and collected data in the z- and y-axes. The second camera was placed 7 meters to the left of the participant and perpendicular to the principle axis of motion (x-axis). The second camera recorded data in the x- and y-axes. Both cameras were mounted on tripods 1.5 meters from the floor and calibrated using a 16-point calibration frame. Direct linear transformation was used to obtain 3D data from multiple 2D views. A JUGS radar gun was used as an immediate source of throwing velocity.

Procedure

Participants reported to the Motor Behavior Lab (Rickel Academic Wing of the Recreation Building). They were instructed to throw a baseball-sized ball (20cm in diameter with a mass of 100 grams) at a mat located 5 meters in front of the participant. All participants completed the throwing trials using their non-preferred throwing arm (left arm).

Participants were randomly placed into four conditions. Condition 1 received augmented information specific to an Internal Focus of Attention. Condition 2 received augmented information specific to an External Focus of Attention. Condition 3 received instructions to scale up on a control parameter for throwing (velocity). Condition 4 did not receive any information or instruction. Augmented information for Internal and External Focus conditions was presented after every fifth trial. Information corresponding to an Internal Focus of Attention was: (a) Turn so your right shoulder is towards the mat, (b) When throwing, shift your weight from the back leg to the front leg, and (c) Arch your back and first accelerate the trunk, then shoulder, then the upper arm, and finally your hand. Instructions for the External Focus of Attention were: (a) Turn sideways so you are facing the south wall, (b) As you throw, shift your weight toward the mat, and (c) Throw the ball as if your trunk and arm were like a whip, like a horseman driving horses. Participants in the Control Parameter condition did not receive any augmented information but scaled up on the control parameter for throwing (velocity of throw). Condition 4 was a Control condition without any augmented information or emphasis on throwing velocity. Each condition consisted of two practice sessions per week for three weeks with at least one day separating each practice session. The participants performed 15 practice trials (throws) in each of the six practice sessions. Throwers in the Internal Focus, External Focus, and Control Conditions were required to throw at a preferred velocity during practice sessions. Participants in the Control Parameter condition were encouraged to increase the control parameter for throwing (velocity) every fifth trial. One week after the sixth practice session, a retention test consisting of 15 trials was performed. Participants threw at a preferred velocity during the retention test with no augmental information or emphasis to increase velocity. Skill improvement was defined by a change in the throwing pattern that favors the open kinetic chain (increase in the number of segments experiencing distal lag during the throw). Each participant warmed up prior to data collection. Warmup consisted of shoulder rotation exercises and five warmup throws with the ball at a preferred velocity. Participants were required to not participate in any throwing activity outside of the lab during data collection.

Design and Analysis

The design is a mixed design with between groups by conditions and repeated measures for sessions. Humeral lag, Forearm Lag, and Hand Lag were the dependent measures. Segmental lag was determined by subtracting the Time-To-Peak Velocity (TTPV) for each proximal segment from the adjoining distal neighbor. Segmental lag was determined from commercially prepared velocity/ time trajectory graphs. A 4x7 (Conditions x Sessions) Multivariate Analysis of Variance (MANOVA) was completed to determine significant dependent measures (segmental lag and peak velocity differences) by independent factors. MANOVA was followed by Discriminant Function Analysis (DFA) in order to identify dependent measures most responsible for significant MANOVA. A Univariate Analysis of Variance (ANOVA) was utilized to further examine differences in means by independent factors for dependent measures identified by DFA. A Scheffe' Post-Hoc test determined the mean scores responsible for significant ANOVA. A Huyhn-Feldt Adjustment was completed for protection against sphericity violations and ω^2 designated effect size. An alpha level of 0.05 will be used for all statistical procedures.

Peak velocity differences were examined to determine if the transfer of angular momentum resulted in an increase in velocity of the distal segments relative to it's proximal neighbor. A positive value would confirm a transfer effect providing segmental lag was also positive.

CHAPTER FOUR:
Results

Introduction

Segmental lag and peak velocity values were considered to determine the effects of instruction on maximizing use of the order parameter. That is, positive segmental lag values and peak velocity differences signify changes that favor the open kinetic chain. Segmental lag was assessed by determining the relative use of the order parameter for throwing (Open Kinetic Chain). Individuals would be classified as a Level 1 thrower when they exhibit arm and elbow extension with no segmental lag. A Level 2 thrower would display lag of the hand relative to the forearm but no lag between the forearm and the humerus. Level 3 throwers would display segmental lag of the forearm and hand with little to no lag between the humerus relative to the trunk. The highest level of throwers, Level 4, would display segmental lag of the humerus relative to the shoulder, the forearm relative to the humerus, and the hand relative to the forearm.

Segmental Lag

MANOVA

The 4x7 (Conditions x Sessions) MANOVA for segmental lag of humeral, forearm, and hand segmental lag indicated a significant condition x session interaction (Wilks' $\lambda = 0.981$), F (54, 351)= 5.32, $p< 0.01$, $\omega^2=0.26$. The Huyhn-Feldt epsilon adjustment did not affect significance. Mean values representing the significant two-way interaction for dependent measures may be found in Figure 1.

Huberty (1994) suggests interpreting significant interactions by identifying Discriminant Function Constructs from main effects separately.

Discriminant Function Analysis by Condition

Box's M Test indicated that homogeneity of variance could be assumed. The discriminant analysis generated one significant function, Wilks' λ= 0.918, χ^2 (9, N= 41)= 356.649, $p< 0.001$, η^2= 0.47. The three variables entering into the function were humeral lag, forearm lag, and hand lag. The standardized matrix coefficients indicated that humeral lag defined the function for Conditions. Table 1 presents the standardized function coefficients and structure matrix coefficients for the independent factor of Condition. Classification results indicated that participants were classified by Condition with 98.2% accuracy. Group centroid data indicated that the control parameter condition was best defined by humeral lag. Table 1 presents Group Centroid results.

ANOVA by Condition

One-way ANOVA with humeral lag as the dependent measure indicated a significant main effect for Condition, F (3, 37)= 57.148, $p< 0.001$, ω^2=0.20 . Scheffe' Post Hoc Analysis indicated that external focus and control parameter conditions were greater (less negative value) than the control condition, which was less than internal focus (which had a greater negative value).

Discriminant Function Analysis by Session

The analysis generated one significant function. Function 1, Wilks' λ = 0.983, χ^2 (18, N=41)= 72.57, $p<0.001$, η^2= 0.702. The standardized function coefficients and structure matrix coefficients indicated that humeral lag defined

Function 1. Table 3 presents the standardized function coefficients and structure matrix coefficients. Classification results indicated that Sessions were classified with an overall accuracy of 79.9%. Group centroid data indicated positive humeral lag best defined session 1 and negative humeral lag defined session 7. Group centroids for the functions appear in Table 2.

ANOVA by Session

One-way ANOVA with humeral lag as the dependent measure indicated a significant main effect, F (6, 117) = 9.657, $p<0.05$, $\omega^2=0.27$. Scheffe' Post Hoc Analysis indicated that humeral lag for sessions 7 had larger negative value than sessions 1, 2, 4, 5, and 6. Session 1 had significantly less negative value than sessions 3 and 7.

Summary of Interaction Results

The mean values for the significant MANOVA interaction (see Figure 1) and consideration of discriminant function analysis results indicated the following differences in segmental lag by condition and session.

Humeral Lag. Analysis indicated initial positive lag values for internal focus at session 1 with sessions 2 through 7 remaining negative. External focus exhibited positive lag values for sessions 1 and 2, with sessions 3 through 7 remaining negative. Control parameter was the only condition to exhibit positive lag values for the later sessions (Sessions 5 and 6). The control condition displayed consistent negative lag values for all seven sessions.

Forearm Lag. Discriminant function analysis did not identify forearm lag as a significant function by condition or session.

Hand Lag. Discriminant function analysis did not identify hand lag as a significant function.

Peak Velocity Differences

In order to identify that the motor system has taken advantage of the order parameter and is increasing velocity of each successive distal segment, there must be an increase in velocity of the distal segment compared to the proximal neighbor. If there is distal lag but no increase in velocity, then the system is not taking advantage of the open kinetic chain. Conversely, if there is an increase in velocity but no distal lag, then the system is not taking advantage of the order parameter. There are varying degrees at which the system can take advantage of the order parameter that may be represented by different absolute lag values (Southard, In Press), but the important issue is whether the Peak Velocity differences are positive or negative. Examination of Peak Velocity Differences by Condition and Session indicates that Peak Velocity Differences are consistently positive and therefore add no information to the analysis of pattern change. In other words, pattern change for this study may be represented solely by segmental lag values.

Peak Velocity of Hand

A 4x7 (Condition x Session) ANOVA indicated a significant main effect by Condition, F (18, 117)= 57.808, $p < 0.01$, $\omega^2 = 0.42$. Scheffe' Post Hoc Analysis indicated that Peak Velocity of the Hand for the Internal Focus and

Control Parameter conditions was greater than that of the External Focus and Control conditions. Peak velocities of the hand may be found in Figure 2.

CHAPTER 5:
Discussion

The results of this study indicate that the hypothesis of no change in pattern as a result of internal focus, external focus or scaling up on a control parameter is rejected. A significant condition x session interaction for humeral lag indicated differential change in pattern by Conditions and Sessions. Emphasizing a focus of attention results in positive humeral lag in early (Session 1) practice sessions for both internal and external focus conditions. In contrast, scaling up on a control parameter results in a change to positive humeral lag in later sessions (sessions 5 and 6). The results of this study support the constrained action hypothesis and the distal to proximal sequence of throwing development.

Southard (2006) determined that as throwers advance in skill level, they exhibit developmental changes that are distal to proximal. That is, lag occurs in the distal segments of the upper limb initially and the more proximal segments experience lag as the thrower progresses in skill level. Poorly-skilled throwers (Level 1) exhibit arm and elbow extension without lag between segments of the arm. A Level 2 thrower usually shows lag of the hand relative to the forearm, but does not display lag between the forearm and the humerus. A Level 3 thrower usually displays segmental lag of the hand to forearm and forearm to humerus, but no lag of the humerus relative to the trunk. The most skilled level of throwers, Level 4, exhibits distal segmental lag for all the segments of the upper limb, hand to trunk. Changes that favor distal segmental lag occurred when the throwers scaled up on velocity of throw.

Not all researchers agree with Southard’s explanation of the sequences of distal lag. Langendorfer and Roberton (2002) found that performers display general proximal to distal pathways as they learn an overhand throw, though these pathways contain idiosyncratic differences among individuals. Langendorfer and Roberton indicated that early in throwing development, initial changes are in trunk kinematics. Changes in trunk kinematics are associated with rotation of the trunk. Consequently, rotation of the trunk affects the more distal segments. They concluded that small alterations in constraints of the large, proximal segments are passed to the smaller, more distal arm segments, causing qualitative changes. They reach this notion by observing that a rotating trunk either precedes or coexists with an increase in humeral and forearm lag. The directions related to both internal and external focus for the present study are directly related to a proximal to distal assumption for the development of throwing patterns. Whereas, scaling up on a control parameter (increasing velocity) has no bias toward a sequence of development.

Past research indicates that if instruction concerning a pattern of movement competes with the pattern’s intrinsic dynamics (natural progression of development), the instruction may impede progression in skill level (Corbetta & Vereijken, 1999; Zanone & Kelso, 1992). That is, if the differences between instructions and intrinsic dynamics are minimized the system is allowed to develop naturally and is able to better self-organize. This self-organization results in a new pattern of movement, as the system shifts to a more attractive way of moving (attractor state). The shifting of attractor states allows the system to maximize use of the order parameter (open kinetic chain for throwing). This effect is seen in the control parameter condition, shown by a positive trend toward humeral lag. Generally, humeral lag became less negative, with lag shifting to positive values at session 5 and remaining positive for session 6. Reduction in negative lag did not occur for other groups. Such development of lag likely occurred because the participants were instructed to scale up on velocity, a control parameter for throwing. Scaling up on a control parameter is a nonessential constraint. That is, it is not essential to the motor pattern itself. The system is allowed to self-organize in an attempt to stabilize, ultimately resulting in the shift to a new attractor state. This employment of a nonessential constraint allows the system to develop according to the natural sequence of development, based on maximizing use of the order parameter for throwing.

If instruction goes against the natural sequence of skill development (internal and external focus), the resulting instability in the system is not beneficial to the development of a new attractor state. Focus instructions likely promoted a premature change that did not remain consistent over practice sessions. Both internal and external focus of attention emphasized a proximal to distal sequence of skill development. The internal focus condition required participants to "Turn sideways and face the south wall" in an attempt to promote trunk rotation and acceleration. They were also instructed to "Arch your back and first accelerate the trunk, then shoulder, then the upper arm, and finally your hand". Such instructions promoted positive humeral lag in session 1, but humeral lag was a consistent negative value for the remaining sessions. External focus required participants to “Turn sideways so you are facing the south wall” in an attempt to promote trunk acceleration, while “Throw the ball as if your trunk and arm were like a whip, like a horseman driving horses”. Similar to the internal focus condition, these instructions also promoted a proximal to distal sequence of development. An external focus of attention exhibited positive humeral lag for sessions 1 and 2, though such benefits were soon lost as humeral lag reverted to consistent negative values for the remaining sessions. It is likely that participants followed direction in earlier sessions, but directions competed with the natural sequence of development. Consequently, humeral lag was not achieved in later sessions because the focus instructions competed with the natural progression of throwing.

The data indicate that instruction may instigate change, but benefits from such change are soon lost if instruction goes against the natural sequence of development. Such findings support the constrained action hypothesis. That is, it is a good idea to reduce instruction relative to limb segments. In fact, data from this study indicate that no instruction at all is of more benefit providing performers scale up on a non-essential variable.

When low level throwers (levels less than Level 4) scale up on velocity the pattern changes when velocity reaches a critical value (Southard, 2002). The new motor pattern is characterized by increased use of the order parameter as the thrower utilizes the transfer of angular momentum to increase velocity of the hand. Participants in the control parameter condition increased use of the order parameter with positive humeral lag during sessions 5 and 6. During session 5, humeral lag shifted from a negative value to a positive value, and remained positive for session 6. An examination of peak velocity of the hand (Figure 2) indicated that pattern change occurred between 13,700 mm/s and 13,800 mm/s. Therefore, the critical value for change from negative to positive humeral lag is estimated to be within the 13,700-13,800 mm/s range. Note that the velocities representing this change are also the greatest velocities across groups which could explain why the control parameter condition was the only condition to change.

It should be noted that a hysteresis occurred for the control parameter condition during the retention session (session 7). It is speculated that this occurred because the critical value was likely exceeded during session 6, where humeral lag remained positive. However, session 7 demonstrated negative humeral lag even though peak velocity of the hand was not significantly different than that of session 6 (see Figure 1 for humeral lag). This may be due to the fact that critical values for control parameters occur in ranges and not at absolute values. The critical value may fluctuate depending on the segment, conditions, and constraints encountered during the performance. It is possible that there was a shift in critical value at Session 7. The increase in critical value may have occurred because of a lack of practice over the preceding weeks, suggesting that the mature pattern reached was not a deep-well (most attractive) attractor state. This would explain why even though participants had mean peak velocities of the hand that were similar in the final two sessions, a fluctuating critical value could have prompted a change back to the less mature pattern.

The notion that instructions are critical to developing throwing pattern is not supported by results of this study. Practice is crucial for the development of proper motor patterns, as it allows the motor system to actively search out the most efficient pattern of moving (Handford et al., 1997). However, it should be noted that completely random searching is time-consuming and may leave the performer with no movement solutions. Instructions may be beneficial but only if they coincide with the natural sequence of development. If instructors know the order and control parameters for a skill, a successful strategy may be to manipulate the task constraints. It is concluded that scaling up on a control parameter and exceeding the critical value is best for promoting a natural sequence of skill development. However, it should also be noted that the data also indicate that when throwing with the non-dominant arm, retention of pattern change is not supported by such a strategy.

References

Bernstein, N. (1967). *The Coordination and Regulation of Movements*. Oxford, England: Pergamon Press.

Burton, A., & Davis, W.E. (1996). Ecological Task Analysis: Utilizing Intrinsic Methods in Research and Practice. *Human Movement Science*, 15, 285-314.

Clark, J.E. A Dynamical Systems Perspective on the Development of Complex Adaptive Skill. In Dent-Read, C. & Zokon-Goldring, P. (Eds.), *Evolving Explanantions of Development* (1997), 383-405. Washington D.C.: American Psychological Association.

Corbetta, D., & Vereijken, B. (1999). Understanding Development and Learning of Motor Coordination in Sport: The Contribution of Dynamic Systems Theory. *International Journal of Sport Psychology*, 30, 507-530.

Crutchfield, J.P., Farmer, J.D., Packard, N.H., & Shaw, R.S. (1987). Chaos. *Scientific American*, 254 (12), 46-57.

Davis, W.E., & Burton, A.W. (1991). Ecological Task Analysis: Translating Movement Behavior Theory Into Practice. *Adapted Physical Activity Quarterly*, 8, 154-177.

Davis, W.E. & Van Emmerik, R.E.A. (1995). An Ecological Task Analysis Approach for Understanding Motor Development in Mental Retardation: Research Questions and Strategies. In: A. Vermeer and W.E. Davis (Eds.), *Physical and Motor Development in Persons with Metal Retardation*. Medicine and Sport Science series, (33-63). Basel: Karger.

Haken, H. (1977). *Synergetics: An Introduction*. Heidelberg, Germany; Springer-Verlag.

Handford, C., Davids, K., Bennett, S., & Button, C. (1997). Skill Acquisition in Sport: Some Application of an Evolving Practice Ecology. *Journal of Sport Sciences*, 15, 621-640.

Heriza, C.B. (1991). Implications of a Dynamical Systems Approach to Understanding Infant Kicking Behavior. *Physical Therapy*, 71 (3), 222-235.

Herkowitz, J. (1978). Developmental Task Analysis: The Design of Movement Experiences and Evaluation of Motor Development Tasks. In: M. Ridenour (Ed.), *Motor Development, Issues and Applications,* 139-164. Princeton: Princeton Book Co.

Huberty, C.J. (1994). *Applied Discriminant Analysis*. New York: Wiley and Sons.

Kelso, J.A.S., Scholz, J.P., & Schoner, G.S. (1986). Non-Equilibrium Phase Transitions in Coordinated Biological Motion: Critical Fluctuations. *Physical Letters*, 118, 279-284.

Kelso, J.A.S., & Schoner, G.S. (1988). Self-organization of Coordinative Movement Patterns. *Human Movement Science*, 7, 27-46.

Langendorfer, S.J., & Roberton, M.A. (2002). Individual Pathways in the Development of Forceful Throwing. *Research Quarterly for Exercise and Sport*, 74 (3), 245-256.

Magill, R.A. (2004) *Motor Learning and Control Concepts and Applications*. New York, New York: McGraw-Hill.

McNevin, N.H., Shea, C.H., & Wulf, G. (2003). Increasing the Distance of an External Focus of Attention Enhances Learning. *Psychological Research*, 67, 22-29.

Newell, K. (1986). Coordination, Control, and Skill. In Wade, M.G., & Whiting, H.T.A. (Eds.), *Motor Development in Children: Aspects of Control and Coordination*, 341-360. Boston: Martinus Nijhoff Publishers.

Poolton, J.M., Maxwell, J.P., Masters, R.S., & Raab, M. (2006). Benefits of an External Focus of Attention: Common Coding or Conscious Processing? *Journal of Sport Sciences*, 24 (1), 89-99.

Roberton, M.A. (1977). Stability of Stage Categorizations Across Trials: Implications for the "Stage Theory" of Overarm Throw Development. *Journal of Human Movement Studies*, 3, 49-59.

Southard, D. (1998). Mass and Velocity: Control Parameters for Throwing Patterns. *Research Quarterly for Exercise and Sport*, 69 (4), 355-367.

Southard, D. (2002). Change in Throwing Pattern: Critical Values for Control Parameter of Velocity. *Research Quarterly for Exercise and Sport*, 73 (4), 396-407.

Southard, D. (2006). Changing Throwing Pattern: Instruction and Control Parameter. *Research Quarterly for Exercise and Sport*, 77 (3), 316-325.

Southard, D. (In Press). *Research Quarterly for Exercise and Sport*.

Thelen, E., & Smith, L.B. (1994). *A Dynamic Systems Approach to the Development of Cognition and Action*. Cambridge, MA: MIT Press.

Totsika, V., & Wulf, G. (2003). The Influence of External and Internal Foci of Attention on Transfer to Novel Situations and Skills. *Research Quarterly for Exercise and Sport*, 74 (2), 220-225.

Vance, J., Wulf, G., Tollner, T., McNevin, N., & Mercer, J. (2004). EMG Activity as a Function of the Performer's Focus of Attention. *Journal of Motor Behavior*, 36 (4), 450-459.

Wulf, G. (2007). Attentional Focus and Motor Learning: A Review of 10 Years of Research. *E-Journal Bewegung and Training*, 1-11.

Wulf, G., & Prinz, W. (2001). Directing Attention to Movement Effects Enhances Learning: A Review. *Psychonomic Bulletin and Review*, 8 (4), 648-660.

Wulf, G., McConnel, N., Gartner, M., & Schwarz, A. (2002). Enhancing the Learning of Sport Skills Through External-Focus Feedback. *Journal of Motor Behavior*, 34 (2), 171-182.

Wulf, G., McNevin, N., & Shea, C.H. (2001). The Automaticity of Complex Motor Skill Learning as a Function of Attentional Focus. *The Quarterly Journal of Experimental Psychology*. 54 (4), 1143-1154.

Wulf, G., Shea, C., & Park, J. (2001). Attention and Motor Performance: Preferences for an Advantages of an External Focus. *Research Quarterly for Exercise and Sport*, 72 (4), 335-344.

Zanone, P.G., & Kelso, J.A.S. (1992). Learning and Transfer as Dynamical Paradigms for Behavioral Change. In G.R. Stelmach & J. Requin (Eds.), *Tutorials in Motor Behavior II*. Amsterdam: Elsevier.

Table 1.

Standardized Canonical Discriminant Function Coefficients for Condition

		Function	
	1	2	3
Humeral Lag	-0.619	0.787	-0.023
Forearm Lag	0.372	0.379	0.849
Hand Lag	0.274	0.547	-0.509

Structure Matrix for Condition

		Function	
	1	2	3
Humeral Lag	-0.656	0.753	-0.049
Forearm Lag	0.387	0.329	0.861
Hand Lag	0.458	0.516	-0.526

Functions at Group Centroids for Condition

		Function	
Condition	1	2	3
1	0.328	0.052	-0.01
2	0.375	0.031	0.011
3	0.516	-0.039	-0.004
4	0.245	-0.034	0.004

Table 2.

Standardized Canonical Discriminant Function Coefficients for Session

		Function	
	1	2	3
Humeral Lag	0.992	0.155	-0.036
Forearm Lag	0.015	0.549	0.838
Hand Lag	-0.086	0.838	-0.543

Structure Matrix for Session

		Function	
	1	2	3
Humeral Lag	0.996	0.064	-0.059
Hand Lag	-0.149	-0.828	-0.54
Forearm Lag	-0.053	0.539	0.841

Functions at Group Centroids for Session

		Function	
Session	1	2	3
1	0.152	-0.036	0.003
2	0.066	-0.001	0.021
3	-0.073	-0.117	0.021
4	-0.013	0.053	-0.045
5	0.045	0.035	0.002
6	0.064	0.04	0.014
7	-0.242	0.026	0.018

Figure Captions

Figure 1. The Segmental Lag for each segment by Condition.

Figure 2. Mean Peak Velocity for Hand by Condition and Session.

Figure 1.

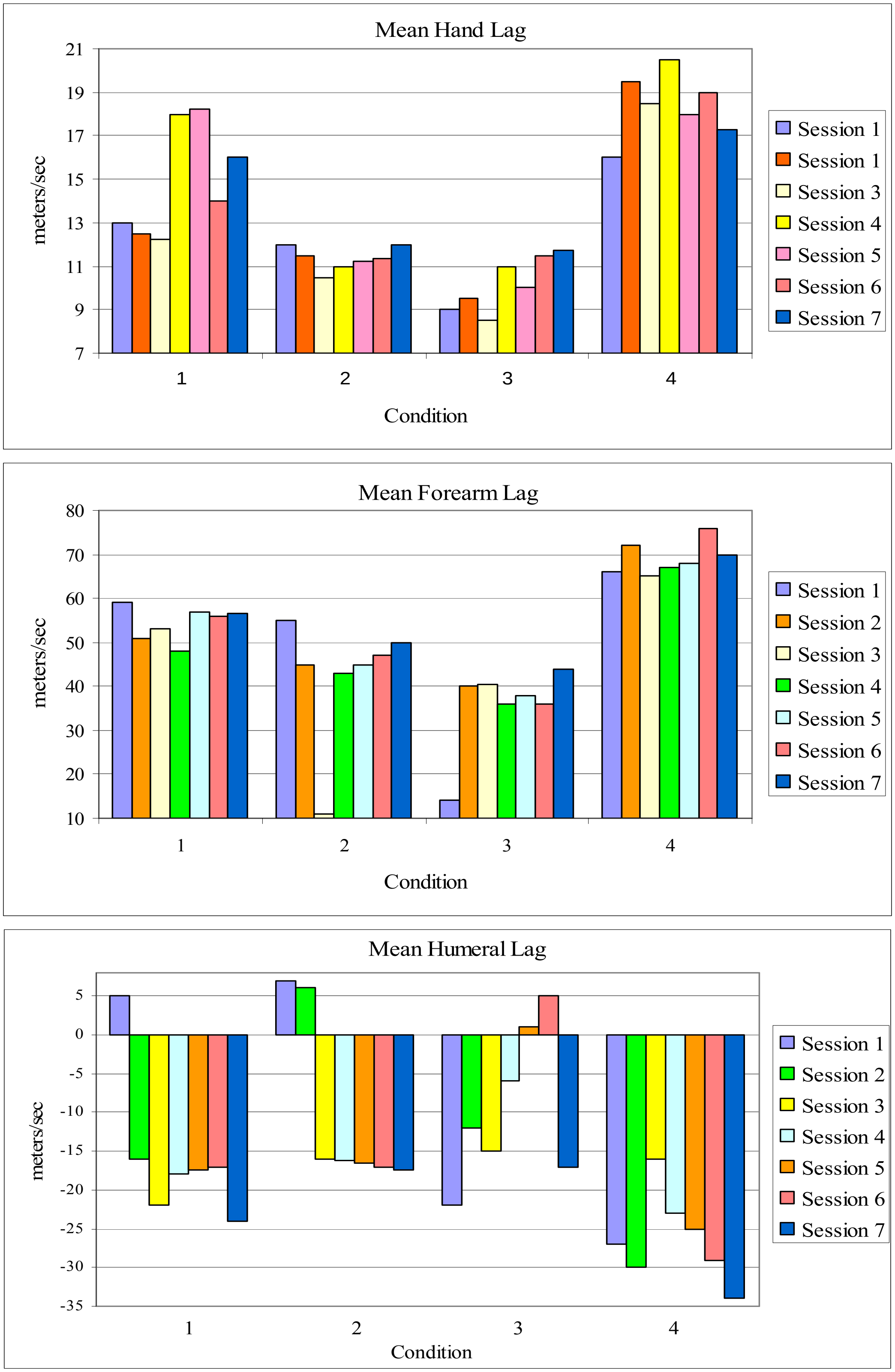
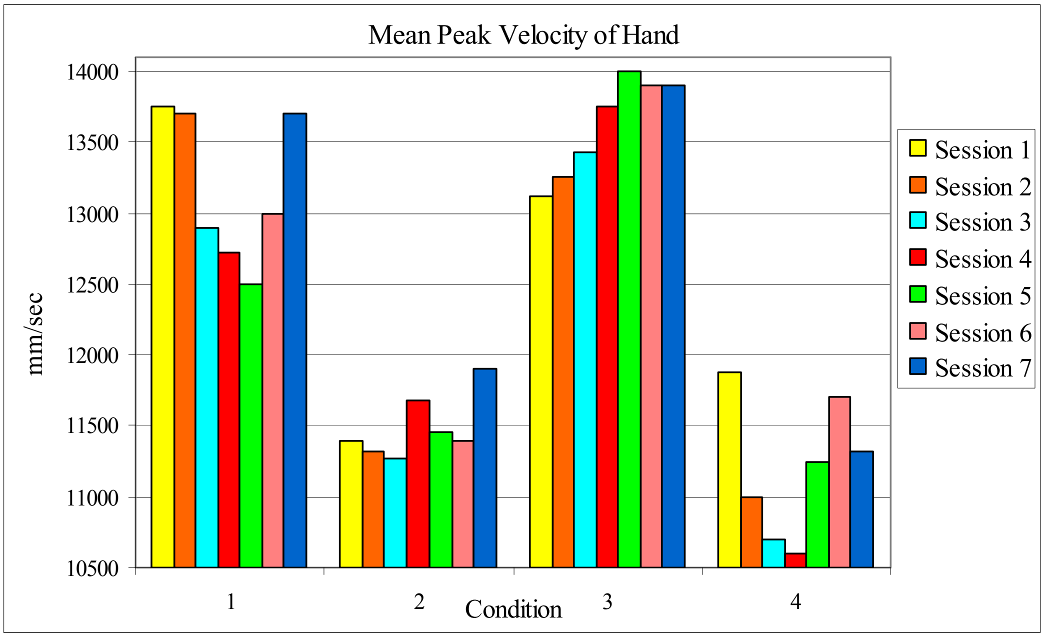

Mean Hand Lag
meters/sec
21
19
17
15
13
11
9
7
1
2
3
4
Condition
Session 1
Session 1
Session 3
Session 4
Session 5
Session 6
Session 7
Mean Forearm Lag
meters/sec
80
70
60
50
40
30
20
10
1
2
3
4
Condition
Session 1
Session 2
Session 3
Session 4
Session 5
Session 6
Session 7
Mean Humeral Lag
meters/sec
5
0
-5
-10
-15
-20
-25
-30
-35
1
2
3
4
Condition
Session 1
Session 2
Session 3
Session 4
Session 5
Session 6
Session 7

Figure 2.



Mean Peak Velocity of Hand
14000
13500
13000
12500
12000
11500
11000
10500
mm/sec
1
2
3
4
Condition
Session 1
Session 2
Session 3
Session 4
Session 5
Session 6
Session 7

APPENDIX A:
Consent Form

Project Title: Changing Motor Patterns: Attentional Focus and Control Parameter

Investigator: JD House

I, ______________________________, hereby certify that I have been told by JD House of the Department of Kinesiology about research concerning Motor Learning/Control and its purposes. I have been told about the procedures to be followed. I understand the possible discomforts, risks, and possible benefits relating to this project.

A written summary of what I have been told is attached. I have been given an adequate opportunity to read the summary. I understand that I have the right to ask questions about any procedure and to withdraw my consent and participation at any time without prejudice to me.

I hereby freely consent to take part in this project.

______________________________ ________________________
Signature of Participant Date

If you have any questions at any time concerning this project or your rights as a participant, please contact: Dr. Dan Southard, Supervising Professor, (817) 257-6869, Dr. Debbie Rhea, Chair- Department of Kinesiology Committee on Safeguards in Human Research, (817) 257-6861.

APPENDIX B:
Written Summary

This experiment is designed to help movement scientists better understand the factors that contribute to the changing of motor skills to a more mature nature. In addition to providing data, participants will have the opportunity to participate in the analysis of movement by viewing and interpreting their own data.

Should you provide your consent, you will be required to throw a baseball-sized ball (using your non-preferred throwing arm) at a padded mat located five meters in front of you. Before collecting data, you will warmup with shoulder stretching exercises and performing five practice throws at a preferred velocity. Your level of throwing will be determined based on the relative use of the Open Kinetic Chain for throwing. You will then be required to return to the Motor Behavior Laboratory for six throwing practice sessions (two sessions per week for three weeks). Each session must be separated by at least one day and each session will include a total of fifteen practice throws. One week following your sixth practice session you will return to the Lab for a final throwing session. Accuracy of throw is not a requirement but you should try to hit the padded mat directly in front of you. There is minimal risk of muscle strain that could occur during trials. If you notice any pain or discomfort while performing trails, let me know immediately and I will discontinue data collection. Should you need medical attention, you should contact your personal physician. Participants are free to withdraw their consent and discontinue participation at any time without penalty of prejudice. Should you choose to withdraw your consent, you will be provided the opportunity to complete an alternate assignment for extra credit. If you have any questions regarding procedure, I will be happy to address them.

I have discussed the above points with the participant. It is my opinion that the participant understands the risks, benefits, and obligations involved with this project.

____

Investigator

ABSTRACT

Changing Motor Patterns: Focus of Attention and Control Parameter

By JD House, M.S., 2008

Department of Kinesiology

Texas Christian University

Thesis Advisor: Dr. Dan Southard, Ph.D.

The purpose of this study is to determine if scaling up on a control parameter serves to change motor patterns more effectively than providing the performer with an External Focus or Internal Focus of Attention. Forty-one college-age students voluntarily participated in this study. The participants were randomly divided into four conditions. Participants in the Internal Focus condition received instruction relative to an Internal Focus of Attention. Participants in the External Focus condition received instruction relative to an External Focus of Attention. Participants in the Control Parameter condition were encouraged to scale up on throwing velocity, which is a known control parameter for throwing. Participants in the Control condition were used as control and received no instruction. The participants practiced throwing with the non-dominant arm twice per week for three weeks, performing fifteen throws each session. Focus instructions and control parameter emphasis were given after every five throws. A Peak Motus 9.2 Motion Analysis System recorded the movement of limb segments. Time to Peak Velocity (TTPV) and Peak Velocity (PV) were digitized for pattern change analysis. A 4x7 (Condition x Session) MANOVA was performed on the dependent measures of segmental lag for the humerus, forearm, and hand. Follow-up Discriminant Analysis and one-way ANOVA were performed on the variable identified as most important in defining differences in data (Humeral Lag). It was concluded that scaling up on a control parameter served to better promote mature motor patterns than focus instructions. However, neither strategy resulted in significant retention of pattern change.