Pattern Change and Performance: Focus of Attention and Control Parameter

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Chapter I

Introduction

A well known saying relative to the performance of motor skill is “practice makes perfect”. This maxim was likely first used by proponents of Throndike’s theory regarding respondent condition back in the 1930’s (Thorndike, E. L., 1932).The idea was that the more you practice at skill the better the connection between a given stimulus to move and a required response. Learning theorists have long determined that it is not just practice that improves performance but how one practices is equally, if not more, important. Motor learning specialists have investigated several aspects of the practice environment. Such research has provided both the learner and instructor with an understanding of how much to practice (Lee and Genovese, 1988, 1989b; and Donovan and Radosevich, 1999; and Shea, Lai, Black and Park, 2001), when to practice (Ammons,1950’ Bourne and Archer, 1956), and what information is most important to the performer following practice (Armstrong, 1950b;Hagman, 1983; Winstein, Pohl, and Lewthwaite, 1994; Tsutsui and Imanaka,2003; Wulf and Toole, 1999). However, recent evidence indicates the performers’ focus of attention may be the most important consideration when developing teaching/learning strategies for skillful behavior.

Focus of attention refers to what learners concentrate on when practicing a skill and may be categorized as one of two different types; internal and external focus (Wulf G., Weigelt, M., Poulter, D., McNevin, N., 2003). Directions that are specific to body segments and their appropriate activities during the movement are internally focused. In contrast to internal focus is external focus which requires the learner to focus on the effect of movement within the practice environment rather than specific body parts (Wulf G., Hob M., and Prinz W., 1998). Since 1998 motor learning specialists have compared internal and external focus and concluded that external focus is most effective for the development and retention of motor skill performance.

The reason suggested for the effectiveness of an external focus has been termed the “constrained action hypothesis” (Wulf, G., McNevin, N.H., Shea, C. H , 2001; Wulf, Shea, Park, 2001; Wulf and Prinz, 2001). According to this hypothesis, focusing attention on the movement effect (external focus of attention, EFOA) allows the movement system to adjust automatically when coordinating and controlling the movement. When consciously trying to control movements by directing specific body segments (internal focus of attention, IFOA) the directions may interfere with the motor system by constraining it to an un-natural internal action. Constrainment is thought to disrupt the automatic control of the motor system and prevent the efficient development of skillful behavior. That is, the idea is that allowing the learner freedom of choice is tantamount to allowing the motor system a natural path toward skill improvement.

An alternative to more traditional viewpoints, but related to constrained action hypothesis, is the Dynamic systems perspective. Dynamic systems proponents view the motor system as a complex and self-organizing system. Dynamic systems viewpoint claims that skill levels may progress as a result of change in the movements themselves and not necessarily because of instructions from outside sources. Motor pattern change and accompanying skill development can be the result of scaling up on dynamic variables called control parameters. Control parameters may be related to the goal of the movement, movement environment, or individual constraints. Control parameters are called non-essential variables because they are not part of the movement itself. Research has provided evidence that supports a pattern change when scaling up on control parameters (Kelso and Schoner, 1988; Southard, 1998; Thelen and Smith, 1994; Thelen, Ulrich, and Wolff, 1991). The connection between external focus of attention and Dynamic Systems perspective is that both allow (to varying degrees) the learner to choose the best route to a skilled performance. In fact, considering the constrained action hypothesis, dynamic systems may prove a better method for skill learning than external focus since there is less constrainment inherent in non-essential variables. However, no one has yet made a comparison of the effect of different focus of attention and control parameters on performance of a motor skill.

Chapter II

Review of Literature

Mechanics of Throwing

Biomechanists typically describe throwing motions as a proximal to distal sequence of increases in velocity resulting from attempts by the performer to conserve angular momentum (Fleisig, Barrentine, Escamilla, and Andrew, 1996; Pappas, 1985; Barthels 1985). Anne E. Atwater (1971) was one of the first to describe this proximal to distal sequence related to executing a throwing pattern. She indicated that during the preparatory phase of the throw there is a sliding hop on the right foot (for right handed thrower) while turning to the right side away from the intended direction of the throw. This is followed by medial rotation of the pelvis which starts turning the trunk toward the target even before the stride foot first makes contact with the ground. Then, forward pelvis rotation precedes the forward rotation of the upper trunk and shoulder. While the trunk rotates forward, the throwing arm shoulder is abducted 90 degrees in a medially rotated position with the elbow fixed at approximately 90 degrees. The shoulder joint action moves the ball toward the shoulder level. As the upper trunk approaches peak angular velocity of forward rotation, the throwing arm begins to rotate laterally through a range of almost 180 degrees. Each distal segment increases velocity which ultimately is transferred to the hand.

Focus of Attention (FOA), Performance, and learning

Focus of attention is selectively concentrating on an aspect of a motor pattern such as spatial or temporal coordination between limbs (Wulf, G., McNeiv, N. H., Fuchs, T., Ritter, F., and Toole, T., 2000). Internal focus directs the learner to specific body segments. External focus is directed away from specific segments and towards the effects that movements have on the environment (Wulf, Hob, and Prinz, 1998, in Wulf, 2007). Wulf, Hob, and Prinz (1998) examined the differential effects of internal and external focus on performance. Thirty-three subjects were required to move from side to side on a ski-simulator with as large an amplitude as possible. The ski-simulator was a moveable-wheeled platform comprised of two codependent footplates, atop two parallel metal rails. The bow-like shape of the rails allowed for sideways movement of the platform. Participants were divided into three groups: group 1 was internal focus, group 2 was external focus, and group 3 was a control group. The Internal focus group was required to exert force on the outer foot while moving on the simulator. The external focus group was directed to exert force on the outer wheel rather than focus on a body segment. The control group was required to move the simulator without any augmented information. Participants performed twenty-two 90 second trials for 2 practice days and twenty-two 90 second trials on a separate retention day. Results indicated greater improvement in the external focus group than the internal focus group. The external focus group also scored better on the retention test than the other 2 groups. There was no difference between internal focus and control group. Researchers concluded that it is best to direct attention towards the apparatus rather than the performer's body. In a follow-up experiment (Wulf, Hob, and Prinz, 1998) sixteen participants were required to balance themselves on a stabilometer. The stabilometer consisted of a 26 inch x 42 inch moveable wooden platform. The platform was constructed so as to allow rotation at its center. The maximal possible deviation of the platform to either side was 15 degrees. Two round red marks with a diameter of 1.5 inches were placed on the platform 6.5 inches from the front edge and 8 inches from the midline of the stabilometer. Participants were instructed to place their feet on the platform so that the tip of each foot touched one of the markers.

Participants in the internal-focus group were instructed to focus on their feet and attempt to keep them level on the stabilometer. The external-focus group was instructed to focus on the red markers and try to keep the markers at level. Participants completed seven 90 seconds trials on 2 consecutive days. Participants were provided with either internal or external focus after every trial. A third day of performance was a retention day with no augmented information. Results indicated that there was no difference in performance between the internal and external groups on practice trials. However, on the retention test the external focus group was significantly better than the internal focus group. They concluded that learning improves significantly more if one concentrates on external focus rather than internal focus.

The apparent advantage of external focus over internal focus has been explained by a "Constrained Action Hypothesis" (McNevin, Shea and Wulf, 2000). This hypothesis suggests that internal focus prevents automatic or natural coordinative responses by the motor system and thereby decreases performance. External focus allows the motor system to progress naturally since there is no direction related directly to body parts. Wulf, McNevin, and Shea (2001) used a dual-task to demonstrate the auotmaticity of movement coordination. Twenty eight subjects were required to balance a stabilometer horizontally for six 90 second trials. Two square markers (2 x 2 cm) were placed on the platform, 9 cm from the front edge and 23 cm from the midline of the platform. Two other rectangular markers (6 x 2 cm) were attached to the platform to the left and right to the sagittal axis of the platform. Markers that were attached to the platform were placed 22 cm from the participant's feet. All participants were asked to put their feet on the platform such that each foot was placed behind one of the markers in the midline of the platform, with the tips of the feet touching the markers. Participants were assigned to one of two conditions, internal or external focus. Internal focus participants were asked to focus their attention on their feet and to try to keep them horizontal. Participants in the external focus condition were asked to focus on the marker attached to the platform. Participants were instructed to concentrate on movement of feet or markers, respectively, but not to look at them. In addition to this, all participants were asked to respond as quickly as possible to an auditory stimulus presented randomly during the balancing task. The required response was to depress a hand held button. The time of response to the auditory stimuli was a reaction time (RT) and a measure of attentional demand. That is, the more an individual concentrates on the primary task the longer it takes to respond to the secondary task. To make sure that the balancing task was not influenced by performance of the RT task, participants performed one stabiolometer task without the RT task in each practice session and retention test. A baseline RT was determined for all participants without performing the stabilometer task. No attentional focus was provided to participants in the retention test. Results indicated that RT (marker of attention) reduced over practice for all participants. However, RT was lower for the external focus group throughout practice and retention sessions than for the internal focus group.

Researchers suggested that RT for the external focus group was lower because they were not focusing on the movement. The external focus allowed for the natural programming of coordinated activity for the limb. Balance improved for both groups (internal and external focus) across practice with the external focus group showing significantly better balance performance than internal focus group on the retention test. Also, the external focus group showed more frequent and smaller amplitude adjustments in posture than internal focus condition. They concluded that as movement becomes automatic the frequency of adjustment for balance increases with smaller amplitudes adjustments. The result is that balance improves and movements become more coordinated. It should be noted that the researchers did not provide evidence of motor pattern change to substantiate claims regarding coordination.

Wulf, Shea, and Park (2001) used a balance task (stabilometer) to examine preference for focus of attention. Seventeen participants were asked to keep a stabilometer balanced for each of four 90 second trials. They were instructed to change their focus of attention from their feet (internal) to markers (external) from trial to trial through out the first day of practice. On the second day they were given a retention test with a choice for focus of attention. On the retention test no further information or reminders regarding focus of attention were provided to the participants. Following the retention test all participants were interviewed regarding their preference for focus of attention. The retention test resulted in better performance for those who chose external focus. In a follow-up experiment the task was the same but this time participants were given 2 days of practice before selecting a focus for the retention test. Results indicated that participants who chose external focus performed better than those who chose internal focus. Researchers reported a postural frequency adjustment with high frequency for external focus and more proficient balance than with internal focus.

Wulf, McConnel, Gartner and Schwarz (2002) examined the effect of internal and external focus on the performance of a sport skill. They required fort-eight novice and advanced volleyball players to perform a volleyball serve. The experiment was conducted in a regular indoor-volleyball court. A target area of 3 x 3 meters was placed in the center of the opponent side of the court and marked with 5 cm wide colored tape to enhance its visibility. A 4x4 meter and 5x5 meter area were marked around the target. If the center of the target area was hit by the serve, 4 points were awarded. A score of 3, 2, or 1 was awarded if one of the three larger target areas or any other area on the opponents' side of court was hit. For balls that were out of bounds or hit the net, 0 points were awarded. A video camera used to record the first three and last three serves for each session. Each participant was provided with the basic techniques of the volleyball serve and the serve was demonstrated to participants. Participants were assigned to either internal or external focus feedback conditions (novice-internal, novice-external, advance-internal, and advance-external). Internal focus group participants were told to, 1) toss the ball high in front of the hitting arm, 2) snap your wrist while hitting the ball to produce a forward rotation of the ball, 3) shortly before hitting the ball, shift your weight from back leg to the front leg, and 4) arch your back and accelerate first the shoulder, then the upper arm, then the lower arm, and finally your hand. The external focus group participants were told to, 1) Toss the ball straight up, 2) imaging holding a ball in your hand and cupping the ball with it to produce forward rotation of the ball, 3) shortly before hitting the ball, shift your weight toward the target, 4) hit the ball as if using a whip, like a horseman driving horses. In each of the two feedback-type conditions, an appropriate feedback statement was given after every 5th trial. Both types of feedback referred to the performers' coordination or movement technique. Accuracy was recorded for each trial. Participants performed 25 practice trials for each of two practice days that was separated by one week. One week after the second practice day, a retention test consisting of 15 trials was performed. No feedback was provided to the participants during the retention test. Results indicated that during practice trials advanced players showed more improvement than novice, and that external-focus feedback was more effective in performance improvement than internal-focus feedback regardless of skill level. Movement form (assessed by an expert ratings regarding the movement form before and after practice trials and after the retention test) improved generally across practice but advanced players and external-focus group showed more improvement than novice and internal-focus group participants. During the retention test, performance was significantly better for advanced participants and external-focus feedback participants than novice and internal-focus feedback participants. Movement form during the retention test improved more for advance participants than novice participants. However, there was no significant change in form for internal and external focus feedback participants. They concluded that external-focus feedback has a significant effect on performance.

Wulf, McConnel, Gartner and Schwarz, (2002) completed a study to examine any possible interaction of feedback frequency and attentional focus. Fifty-two participants were required to perform a lofted soccer pass. Participants were instructed to approach the ball from an angle of approximately 45 degrees, perform a relatively long last step, and position the non-kicking foot to the side of the ball. Participants were given one demonstration of the task by kicking the ball at a target placed 15 meters away from the participants. The target was 1.4 meter in length and height, and raised to 1 meter above the ground. The central target area was 80 cm x 80 cm with two zones (15 cm wide), surrounding the central target. If the ball hit the central area, 3 points was awarded. A score of 2 or 1 point was awarded if the larger target area was hit respectively. Participants were divided into four groups according to focus (internal and external) and feedback frequency (100% and 33%). Participants performed 30 practice trials followed by 10 trials for a retention test. The retention test was separated by one week from the last practice trial. No feedback was provided during the retention test. The internal focus group was told to, 1) position your foot below the ball's midline to lift the ball, 2) position your body weight and non-kicking foot behind the ball, 3) lock your ankle down and use the instep to strike the ball, 4) keep your knee bent as you swing your leg back, and straighten your knee before contact, and 5) strike the ball, the swing of the leg should be as long as possible. The external-focus group was told to, 1) strike the ball below its midline to lift it; that is kick underneath it, 2) be behind the ball, not over it, and lean back, 3) stroke the ball toward the target as if passing to another player, 4) use a long-lever action like the swing of a golf club before contact with the ball, and 5) to strike the ball, create a pendulum –like motion with as long a duration as possible. Results indicted that for practice trials all groups showed an increase in the accuracy of passes. However, the external-focus feedback group (ext-100 and ext-33) was more accurate than internal-focus feedback group (int-100 and int-33). For internal-focus conditions, the33% group (intl-33) was more accurate than 100% (int-100). For external-focus conditions, the 100% group (ext-100) was more accurate than 33% (ext-33). The retention test indicated a general increase in accuracy across trials. It was concluded that internal-focus of attention improves performance and learning if frequency of feedback is reduced. The 100% feedback condition was more effective in improving performance and learning for external-focus feedback. Results indicated that frequency of feedback has a differential effect depending upon the focus of the performer.

Vance, Wulf, Tollner, McNevin, and Mercer (2004) examined EMG to indicate changes in neuromuscular activity associated with internal and external focus. Eleven participants performed a biceps curl task under both internal and external focus of attention. Participants were asked to perform 2 sets of 10 repetitions under each focus of attention. For internal focus participants were asked to focus on their biceps muscle during the task. For external focus participants were asked to focus on the curl bar. Participants were instructed to look straight ahead and focus their concentration on the curl bar or the biceps muscle. Participants were not instructed regarding the speed of execution. An electrogonimeter measured elbow flexion and extension angle. Surface mounted Ag/AgCL electrodes were used to measure electric activities for the biceps and triceps. Participants performed unweighted, maximal-effort isometric contraction (MIC) of the elbow flexors at 90 degrees of elbow flexion an full elbow extension before beginning the curl task. EMG magnitude was determined by a percentage of MIC. Participants performed four sets of curls counter-balanced by internal or external focus. Participants were given a rest period of about 5 minutes between each of the MIC trials and each of the attentional focus conditions. Results indicated that movements were generally executed faster (higher angular velocity) with external focus. Average EMG activity was not different between both groups but it generally increased across repetition (and sets). Integrated EMG increased across repetitions but was smaller in external focus condition than in the internal focus condition. Researchers concluded that external focus improved movement automaticity, economy in the movement production, and required less initial motor unit recruitment. However, movement speed could account for the difference in results. A second experiment was completed to control for velocity differences. In the second experiment, EMG activity in internal and external focus conditions were compared when the timing of movement execution was constant. Participants were instructed to synchronize the time of their biceps curl so that the end of each upward and downward movement coincides with one click on a metronome. Results indicated that integrated EMG activity was less for the external focus condition. Collectively, results from both experiments suggested that focusing on movement effect may result in better coordination of agonist and antagonist muscles for improved movement economy. However without a control group it is difficult to definitely attribute changes in neuromuscular activity to internal or external focus of attention.

Dynamic Systems, Pattern Change and Performance

Past theories of motor coordination have required that instructions for movement coordination be stored centrally as a program (Keele, 1968), a perceptual trace (Admas.1971), or a schema (Schmidt, 1980). When a particular movement is required the proper stored information is first selected by the motor system and then sent to the correct muscles with the right timing to accomplish the movement. Dynamic systems is a departure from past "motor program" theories in that movement patterns have self-organizing properties where order and regulation may be due to the dynamics of the movement itself (Kelso, 1982). That is, there is no need for" between things" such as program or schema to direct movement and instigate changes in motor patterns.

There are four relatively important concepts that are related to a dynamic systems explanation of pattern change- degrees of freedom, control parameters, critical value, and order parameters. The degrees of freedom of any system are the number of independent coordinates needed to identify the positions of the elements in the system without violating any geometrical constraints (Turvey, Fitch, and Tuller, 1994). In other words Degrees of freedom are the number of decisions that the motor system must address in order to perform successfully. For example we can move the arm in three planes with at least 10 muscles at the shoulder joint; the forearm moves in two planes with at least 6 muscles acting on it, and the hand can move in 2 planes of motion with at least 6 muscles that allow such motion. That makes a total of 26 degrees of freedom that needs to be regulated for a given movement of the upper limb. In addition, there are at least 100 motor units per muscle which (if controlled individually) make around 2600 degrees of freedom to move the upper limb. In order to perform successfully all degrees of freedom must taken into consideration. Constraints delimit the possibilities for movements and help control degrees of freedom.

Constraints set boundaries for the behavior of systems. They narrow the possibilities for successful coordination and thereby reduce the number of decisions required by the motor system. Constraints have three sources: environmental, individual, and goal (Newell, 1985). Environmental constraints refer to the physical as well as sociocultural environment surrounding the individual. For example, the requirement to walk on an uneven terrain may require a different walking pattern than walking on smooth terrain. Individual or organism constraints are those that are embodied in the individual. For example, walking with sever ankle injury requires a different gait. Goal constraints are those which arise from the task at hand. For example, the goal to move fast requires a running pattern that differs from a walk.

Constraints that are scaled to sufficient value may become control parameters and instigate instability in patterns. Control Parameters are not encoded with change and have no intent to change. When constraints are scaled to a critical value they become control parameters and force the motor system to behave or coordinate differently .Before change occurs there must be variability in the motor system. A critical value is the value at which a constraint increases variation in pattern and causes instability. Instability is a requirement for pattern change. After change occurs patterns may return to stability. Stable patterns of movement are called attractor states because they are the preferred pattern for the individual. The characteristics of a new pattern are determined by the order parameter. Order parameters reflect change in pattern by allowing the system to organize within a context of constraints. Order parameters are usually mechanical principles that the motor system attempts to take advantage of to perform movements effectively. The order parameter acts to constrain or compress the degrees of freedom available to the elemental components.

Southard (1998) determined control parameters and the order parameter for throwing patterns. Twenty participants (20-24 years) were placed into one of four groups according to their throwing level. He required each participant to scale up on the velocity of throw by throwing at 25%, 50%, 75% and maximum velocity. In addition, he added mass to proximal and distal arm segments for each of the throwing velocities. He concluded that by increasing proximal segment mass and/or throwing velocity, throwing patterns move towards maximal use of the open kinetic chain. He also concluded that the open kinetic chain served as an order parameter for throwing patterns. In a later study, Southard (2002) also provided evidence for critical values relative to change in throwing pattern. Thirty-six (age 20-27 years) participants were divided into four groups according to their throwing level. He required subjects to increase throwing velocities in 10% increments from 10% to 100% velocity. He then determined at what percentage the pattern of throw began to lose stability. He found that critical values (velocity where the system becomes unstable and eventually changes) for throwing level 1 occurred for the wrist joint at 40% and 90% of maximum velocity and for elbow joint at 20% of the maximum velocity. For level 2 it occurred at 10% and 90% of maximum velocity for the wrist joint and 10% for elbow joint. The critical value for level 3 occurred at 10% for the elbow and for level 4 it was 100% for the wrist. He concluded that the control parameter of velocity acts independently by segment when instigating change in pattern for throwing.

Clark and Philips (1993) used the dynamic systems approach to explain the development of new walking patterns for infants. The researchers tested the stability of walking patterns by attaching a weight to the ankle on infants and adults (for infants, weight was 5% of their body weight and for adults it was 7.5% of their body weight). They found that by scaling up on a control parameter, infants exhibited adult-like coordinative patterns. That is, the thigh acted as a forcing oscillator that drove ahead of the shank, stopped, and reversed its direction, leaving the shank to swing through ahead of the thigh before heel strike. Without attaching weight their thigh-shank coordinative pattern was different from that of an adult. They predicted the infants' strength of the thigh flexors acts as a control parameter for the development of the coordination of the thigh-shank for walking. It was suggested that an adult like phasing relationship between the two segments emerges developmentally when the infant's thigh can move faster than the shank.

Thelen and Ulrich (1991) used a dynamic systems approach to explain infant stepping on a treadmill. They examined 13 infants from one month to ten months of age. The infants were required to walk on a treadmill with support help from the researchers. The treadmill was constructed with two parallel spilt belts. They manipulated the speed of each individual belt to determine how well the infants could alternate steps despite the perturbation of having one leg moving at twice the speed of the other leg. They expected that if the attractor state were stable, the infants would immediately correct by maintaining alternating steps. If the pattern were a less stable state then gait would be easily disrupted. They found no disruption in the gait pattern of infants despite of change in treadmill's speed and alternation of the speed of treadmill's belts. Results indicated four possible control parameters for changing an infant's stepping pattern: (1) overall rate of general maturation; (2) developmental changes in proportion and composition of legs; (3) overall changes in arousal or mood; and (4) changes in the postures and movements of the legs.

Thelen, Sakala, and Kelso (1987) found that adding mass to the legs of 6-weeks-old infants shifted the laterality of the kick so as to maintain a base line. They video taped infants kicking in water (water level was up to their nipple) and added weight to their kicking leg. They measured their kick rate and kick amplitude, velocity and duration of kick. They found that, (1) weighting one leg shifted the lateral preference of kicking in favor of a higher kick rate in the unweighted leg, (2) amplitude and velocity increased in the unweighted leg when one leg was weighted, and (3) movement durations were significantly slower only in the weighted condition in water. They concluded that manipulating the mass of lower limb segments can create instability in the system change the kicking pattern.

Ecological Task Analysis

Traditionally, instructors have approached the task of motor learning by identifying individual parts of a skill and then ordering them for the learner 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 learner is ready to proceed with the entire skill. The problem with this theory is that the task goals for separated parts of a skill are usually 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 for the skill is oftentimes not taken into account. Because each performer is a unique individual with a wide variety of constraints, both internal and external, 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 strategies. Ecological Task Analysis (ETA) relates to the dynamic system approach by analyzing the various constraints including task constraints, internal constraints, and external constraints (Burton & Davis, 1996). The concept of ETA is a more accurate depiction of the categories of constraints and how it is necessary for the performer to find, adapt, and use the constraints to improve the efficiency of the task at hand (Burton & Davis, 1996). Ecological Task Analysis involves four primary steps (Davis & Burton, 1991). The first step is to establish a goal for the task. It is imperative that the goals of the task at hand 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 individual 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 individual 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 individual to naturally adapt to unforeseen changes. The use of the individuals' 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 performance consistency as these movement solutions are applied to similar movement problems (Davis & Burton, 1991). That is, ETA promotes a mutual sequence of skill learning. This is accomplished by establishing goals for the task and emphasizing non-essential variables (control parameters) in instructional strategies. The ETA method of instructions (Dynamic system approach) requires less specific information be provided performer than the successful external focus condition. If the constrained action hypothesis is valid then scaling up on a control parameter (an ETA strategy) should increase performance better than external focus of attention.

Speed-Accuracy Trade-Off

Previous research has indicated that accuracy may be adversely affected by velocity. This is commonly refereed as the Speed-Accuracy Trade-Off. However, recent findings challenge the validity of that assumption.

Indermill and Husak (1984) demonstrated a speed-accuracy trade-off in a throwing activity. They divided participants into 3 velocity conditions according to throwing velocities: 50%, 75% and 100% of maximum velocity. Accuracy was measured by hitting a ball on a circular target. Target had five colored concentric rings with bottom edge of center ring 4 feet above the ground. The center ring had diameter of 9.25 meters. The concentric rings progressing outwards and each had a width of 4.75 meters Hitting a center ring was measured as five points and hitting the outer rings decreased progressively from four to zero points. Results indicated that accuracy increased from 50 % to 75% and then decreased at 100% velocity. They concluded that at higher velocity all muscles in a complex movement, like throwing, generate force inconsistently at near maximum velocity which decreases accuracy.

Van Den Tillaar and Ettema (2003 a) demonstrated that as accuracy was emphasized velocity decreases. Nine experienced handball players were required to throw a handball in five different conditions: in condition 1 maximum velocity was emphasized; in condition 2 first priority was to throw a handball as fast as possible and second to throw accurately; in the third condition velocity and accuracy were emphasized equally; in a fourth condition the main priority was accuracy and a secondary goal was velocity, and in a fifth condition the only priority was to hit the target. Results indicated that when accuracy was emphasized velocity decreased. Van Den Tillaar and Ettema (2003 b) also examined throwing coordination in relation to accuracy and velocity. Results indicated that when accuracy was emphasized velocity decreased but movement form, that is, relative timing of body segments did not change. They concluded that highly experienced participants were able to overcome the general speed-accuracy trade-off and were less likely to change their movement form.

Van Den Tillaar and Ettema (2006) determined that there was no speed accuracy trade off for either novice or expert performers. Participants at each level were divided into five instructional groups. Group one emphasized maximum velocity. Group 2's first priority was to throw a handball as fast as possible and a secondary goal was to throw accurately; the third group was a velocity and accuracy group where they emphasized speed and accuracy equally. The fourth group emphasized accuracy with speed as a secondary goal and the fifth group only emphasized accuracy. They concluded that experts were better in speed and accuracy than novices. However, there was no speed-accuracy trade-off for the different groups.

Southard (1989) examined changes in pattern and accuracy for a striking task. Participants performed a striking movement under three conditions: hit a ball off of a tee with the hand without regard to accuracy; hit a target with the ball with no emphasis on velocity, and hit the target as accurately and as fast as possible. Results indicated that striking at fast velocity improved movement form and emphasizing only accuracy reduced the efficiency of striking pattern. He concluded that accuracy was not affected by an increase in velocity when accompanied by improved movement form.

The purposes of this study were to compare changes in motor pattern and performance of individuals when utilizing internal, external, or dynamic system perspective when learning the fundamental skill of throwing. The hypotheses for this study are: 1) that scaling up on a control parameter while emphasizing on accuracy will result in change toward a more mature pattern better than internal and external focus; 2) scaling up on a control parameter while emphasizing on accuracy will result in significantly better performance; and 3) scaling up on a control parameter while emphasizing on accuracy will result in better retention of pattern and performance.

Significance of study

The study should help kinesiologists to understand the most effective way to instigate motor pattern change while emphasizing performance. Such information should provide coaches, performers, and movement based professionals with strategies for learning and improving motor skills.

Chapter III

Method

Participants

Forty-four college age students were participants for this study. Four participants were dropped from the study after missing scheduled practice sessions. All participants were right-hand dominant with no physical limitations to prevent the development of a mature throwing pattern. Participants signed a university approved consent form prior to participation.

Apparatus

A Peak motion analysis system was used to collect and digitize data. Two digital cameras captured participants' motion during a throwing task. One camera was placed 5 meters from the participant and perpendicular to the principle axis of motion (x axis). The first camera captured motion in the x and y axes. A second camera was placed 5 meters behind participants and recorded data in the z and y axes of motion. Both cameras were placed on a tripod at 2.5 meters from the floor. The system was calibrated with a 16 point calibration frame. The cameras were synchronized with a remote sensing unit. Direct linear transformation was then used to obtain 3D data from multiple 2D views. A Jug's radar gun was used to measure throwing velocity.

Procedure

Participants were randomly placed into 4 groups. Group 1 was designated the internal focus group. Group 2 was designated the external focus group. Group 3 was designated the control parameter group, and the fourth group was a control group.

Participants in each group were required to throw a baseball size ball (20 cm in diameter and 100 gms in mass) for 15 trials at a target 5 meters to their front. Participants in Internal Focus, External Focus and Control group threw the ball at a preferred velocity (approximately 50% of maximum) and accuracy was stressed. Participants in the Control Parameter group were encouraged to increase their throwing velocity and also throw as accurately as possible. Participants threw with their non-dominant arm (left arm). Each participant was required to warm up by completing 5 throws at a preferred velocity. Each participant threw from the same location to ensure constant throwing distance to the target. The target was octagon in shape (25 cm x 25 cm) located 5 meters in front of the participants. An 'X' mark was placed in the octagon target for clear visibility of target center. Marks (10 cm in length) were placed around the octagon target in all eight directions (corresponding to each side of the octagon) with a gap of 10 cm between each mark. An outside octagon (52 cm x 52 cm) surrounded the smaller target octagon at a distance of 41 cm from target center. The markings on the target were also used to determine ball placement relative to target center. The markings and target were easily visible and of red color over a blue color base. The target was 1.7 meters from the floor and was in line with the participants' lead shoulder. See figure 1 for a representation of the target.

Participants reported to the motor behavior lab two times a week for 3 weeks for a total of 6 sessions. A seventh retention session required participants to return to the lab one week following the sixth session. Participants in the Internal Focus condition were given the following augmented information to internally focus on their throwing performance: 1) “turn so your right shoulder is closer to the mat”, 2) when throwing shift your weight from back leg to front leg, and 3) “arch your back and first accelerate the trunk, then shoulder, then upper arm, and finally your hand”. Participants in the External Focus condition were given the following augmented information so as to direct their focus externally: 1) “turn sideways so you are facing the south wall”, 2) when throwing shift your weight toward the mat, and 3) “throw the ball as if your trunk and arm were like a whip, like a horseman driving his horses”. Participants were initially provided instructions prior to the first trial. Augmented information was then provided after every 5th throw during each practice session. Participants were not provided any information during the retention session. Participants in the Control Parameter condition were encouraged to scale up on the control parameter of velocity after every 5^{th} throw and did not receive any additional augmented information. Participants of the Control Group condition did not receive any augmented information nor did they scale up on the control parameter. The control group threw for the 6 practice sessions and a retention session same as the experiment groups. To measure accuracy of throw, ball placement on the mat was recorded for every trial. The researcher placed himself behind the participants in order to see the correct ball placement on the mat and each location of the ball was placed on a scaled paper model. A correlation of (r = .85) between ball placement on the target and placement on the scaled model supported the accuracy of ball placement data. All participants were asked not to participate in any kind of throwing activity during the seven sessions of data collection.

Design and Analysis

This study utilized a mixed design with between groups by condition and repeated measures for sessions. Segmental lag and accuracy of throw were dependent measures. Trajectory graphs for each segment were digitized to determine the segments' time to peak velocity relative to a common start point. Segmental lag was determined by subtracting time to peak velocity of each proximal segment from its distal neighbor (Humerus – trunk (Hum-T), Forearm – Humerus (F-Hum); and Hand – Forearm (H-Fore)).Accuracy was determined by radial error. Radial error was determined by the square root of the sum of error in the x and y axes squared (Pythagorean Theorem).The independent factors for this study were condition and sessions. A 2-way (4 x 7) Multivariate analysis of variance (MANVOA) was completed on the three dependent measures of segmental lag (Hum-T, F-Hum, H-Fore). MANOVA was followed by Discriminant Function Analysis (DFA) in order to identify significant functions related to the main effects and interaction MANOVA. Univariate analysis (ANOVA) was used to determined differences in identified functions by independent factors. Scheffe post hoc identified measures responsible for significant ANOVA. Hyun-feldt adjustment was completed for violation of spherecity. A two-way (conditions x sessions) ANOVA was completed to determine significant differences in radial error and coefficient of variation of radial error. An alpha level of .05 as selected for all statistical parameters.

Chapter IV

Results

Segmental Lag

The 4 X 7 (Condition x Session) MANOVA for humeral, forearm, and hand segmental lag indicated a significant condition x segment interaction (Wilks' Λ =.968, F (54,360) = 2.41, p<.05, ω^2 = .18). The Huyhn-Feldt epsilon adjustment did not affect significance. Huberty (1994) suggests interpreting significant interactions by identifying discriminate function constructs from main effects separately.

Discriminate Function Analysis by Condition: Box's M test indicated that homogeneity of variance could be assumed. The discriminated analysis generated one significant function (Wilks' Λ =.925, X^2 (9, 4276) = 310.16, p <.001, η^2 = .274). Standardized function and structure matrix coefficients identified significant function as humeral lag. 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 99.1% accuracy. Group centroid results indicated that the internal focus and control parameter group are best identified by the significant function of humeral lag. Group centroid results may be found in table 1.

One-way ANOVA with humeral lag as the dependent measure indicated a significant main effect by condition, F (3, 37) = 29.65, p< .002, ω^2 = .23. Scheffe post hoc analysis indicated that internal focus and control group had significantly greater negative values than external focus and control parameter group which were not significantly different from each other. See figure 2 for a graphic representation of Humeral lag by condition and session.

Discriminates Function Analysis by Session – The analysis generated one significant function (Wilks' Λ =.992, X^2 (18, 4276) = 31.024, p <.05, η^2 = .08). Standardized function and structure matrix coefficients indicated that the significant function was humeral lag. Table 2 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 87.2% accuracy. Group centroid data indicated that humeral lag best identified session 1. Group centroid results may be found in table 2.

One-way ANOVA with Humeral Lag as the dependent measure indicted a significant main effect by session F (6, 34) = 4.15, p< .001, ω^2 = .31. Scheffe post hoc analysis indicated that session 1 had significantly less negative lag than session 4 with no other significant differences by session.

Summary of interaction results

The mean values for the significant MANOVA interaction (see figure1) and consideration of DFA results indicated the following differences in segmental lag by condition x session.

Humeral Lag – Analysis indicated negative values for internal focus and external focus for all 7 sessions. The control parameter group had one positive session (session 5) with remaining sessions having negative values. The control group had consistent negative values for all seven sessions. The data indicated that session 1 expressed less negative values for the internal and external focus groups. When data is collapsed by session the control parameter and external focus groups have lower but consistently negative values. The only exception is session 5 of the control parameter group. The control group differed from the focus groups and control parameter group with lower negative values (closer to positive) in the retention session.

Forearm Lag – Discriminate function analysis did not identify forearm lag as a significant function. A graph of means for forearm lag may be found in figure 3.

Hand Lag - Discriminate function analysis did not find out hand lag as a significant function. A graph of means of hand lag may be found in figure 4.

Peak Velocity Differences

In order to identify that motor system has taken advantage of the order parameter and is increasing velocity of each successive distal segment there must be an increase in the velocity of the distal segment compared to its proximal neighbor. If there is a 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 order parameter. There are varying degrees at which at which the motor system can take advantage of order parameter that may be represented by different velocities (Southard, in press), but the important issue is whether the peak velocity differences were positive or negative. Examination of peak velocity differences by condition and session indicated that peak velocity differences were 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. Graphs of peak velocity differences may be found in figure 5.

Accuracy

Two-way ANOVA for Radial Error. ANOVA (condition x session) indicated a significant interaction $F(18, 148) = 3.41$, $p<.001$, $\omega^2 = .27$. Generally, accuracy scores improved with practice over the first 6 sessions except for the control parameter and control groups. The control parameter group for sessions 5 and 6 was significantly more accurate than other sessions. In fact, sessions 5 and 6 for control parameter group were more accurate than the average accuracy for remaining groups. See figure 6 for a graph of accuracy scores.

Two-way ANOVA coefficient of variation of radial error. Condition x session (ANOVA) indicated a significant main effect by session $F(18, 148) = 3.52$, $p<.001$, $\omega^2 = .27$. Scheffe post hoc analysis indicated that session 1 was greater than session 6. Variability of radial error reduced over the practice sessions for Internal Focus and Control groups but not for External Focus and Control Parameter groups. But session 6 of control parameter group had lowest variability across conditions and sessions. See figure 7 for a graph of variability of radial error.

Chapter V

Discussion

Results from this study indicate that hypothesis one (scaling up on a control parameter while emphasizing accuracy will result in change toward a more mature pattern better than internal and external focus conditions) is not accepted. The data indicated that changes in the control parameter condition were significantly better (closer to positive humeral lag) than the Internal and Control groups but not significantly different from the external focus group. Hypothesis two (scaling up on a control parameter while emphasizing accuracy will result in significantly better performance (accuracy scores)) is not accepted. The data indicates that the external focus condition was significantly more accurate than the control parameter condition with no other significant differences by group. However, it should be noted that the least accurate condition (control parameter) also had the most accurate sessions (sessions 5 and 6). Hypothesis three (scaling up on a control parameter while emphasizing accuracy will result in better retention of pattern and performance) is not accepted. For pattern retention: the only significant differences by session for humeral lag was that session 1 was significantly better (less negative lag) than session 4 (greater negative lag). There were no differences between session 7 (retention session) and remaining sessions which indicates that participants across groups did not significantly change following a ten day layoff from practice. In fact, the best value for humeral lag (closest to positive) was in the control group. For performance retention: the retention session is most accurate for the focus groups and significantly lower than earlier sessions (1 and 2) for the focus conditions. However, the retention sessions are greater than previous sessions for Control Parameter and control groups (sessions 5 and 6 for Control Parameter; and sessions 2,4, and 5 for Control Group). Following is a discussion of each of the hypotheses.

Scaling up on a Control Parameter while Emphasizing Accuracy will Result in Change Toward a More Mature Pattern

The significantly lower negative values in humeral lag experienced by both the External Focus and Control Parameter groups supports the "constrained action hypothesis." That is, focus that is not related to specific body parts resulted in changes closer to a mature pattern. The only way that a mature pattern is accomplished for this data is when humeral lag is a positive value. The control parameter group was the only group that experienced positive lag for all segments (session 5). Examination of velocity data (Figure 5) indicates that the greatest velocity of throw (represented by hand velocity) was also the session where positive humeral lag occurred. A dynamic systems interpretation would indicate that the sudden change likely occurred because throwing velocity reached a critical value resulting in positive humeral lag. Humeral lag did not remain for sessions 6 and 7. Hand velocities for sessions 6 and 7 were lower than session 5 but not significantly different. It may be that the lower velocities for sessions 6 and 7 were not statistically significant but below the level of a critical value for pattern change. Therefore, participants returned to the most attractive pattern for accomplishing the throwing task.

Scaling up on a Control Parameter While Emphasizing Accuracy Will Result in Significantly Better Performance

The finding that the focus conditions improved their accuracy with practice is in line with previous findings regarding focus of attention and performance of motor skills (Wulf, Hob, and Prinz, 1998, in Wulf, 2007; Wulf, McNevin, and Shea, 2001; Wulf, Shea, and Park, 2001; Wulf, McConnel, Gartner and Schwarz, 2002; and Vance, Wulf, Tollner, McNevin, and Mercer, 2004). The Control Parameter Group was the least accurate but only significantly less accurate than the most accurate External Focus group. In light of the accuracy findings, it should be noted that the Control Parameter Group had the most accurate sessions (5 and 6). The pattern of data for performance is somewhat in line with changes in humeral lag. That is, humeral lag for the Control Parameter Group is positive at the same session (session 5) that accuracy was best across groups. The fact that velocity increased at session 5, pattern changed, and accuracy improved would support earlier findings regarding the speed accuracy trade-off (Southard, 1986, 1989). That is, accuracy may improve with an increase in velocity providing the increase in velocity results in a change to a more mature pattern of movement.

In order to examine the possibility that accuracy is the result of pattern change and velocity increase, follow-up correlations were determined between overall humeral lag, velocity of the hand and radial error. For comparison, zero order correlations were determined for the same variables but only for the Control Parameter Group at Session 5. Results indicated that correlations across groups and sessions were low and not significant ($r = .045$ radial error with humeral lag; $r = .012$ radial error with hand velocity). However, correlations were significant when examining only data for the Control Parameter Group at Session 5 ($r = -.259$ radial error with humeral lag; $r = -.186$ radial error with hand velocity). The correlational data support an increase in performance accuracy with increases in hand velocity and changes toward a mature pattern. This conclusion, however, is questionable with the present data since accuracy remains consistently high (low radial error) for session 6 even though the pattern returns to a less mature attractor level.

Scaling Up on a Control Parameter Will Result in Significantly Better Retention of Pattern and Performance

Changes in pattern for this study are recognized by differences in humeral lag. Directional change toward a mature pattern could be represented by a decrease in negative values for humeral lag or a change to a positive value for humeral lag. Neither of the experimental conditions (Internal Focus, External Focus, and Control Parameter) demonstrated retention of pattern change toward a mature pattern. Taking a dynamic systems perspective, the conclusion would be that performers preferred an attractor state that did not favor changes toward a mature pattern for humeral lag. When instructions were removed and velocity was not emphasized humeral lag increased in negative value in comparison to the session(s) closest to positive lag. Directional focus results in early movement toward a mature pattern and scaling up on velocity results in a change in pattern at a critical value. However, such changes are not retained following 10 days of no practice and the removal of focus and velocity emphasis.

Performance data indicates that accuracy was not only retained but improved for the Focus groups and not for the Control Parameter and Control groups. The increase in accuracy for Session 5 paired with an increase in velocity in the same session does not support a traditional speed accuracy trade-off. In addition the increases in accuracy for the Focus groups, while velocity remained generally constant, does not indicate that velocity is a primary factor in attaining accuracy. The accuracy data for the Control Parameter group supports the position by Southard (1989) that accuracy and speed are accompanied by a change toward a more mature pattern.

The only condition that registered a lower error score with practice and accompanying decrease in variability were participants in the Internal Focus condition. Apparently, instruction that focuses on specific body segments aids performance but did not aid a change in pattern. Interestingly, sessions 5 and 6 were the least variable in the control parameter condition where humeral lag was positive for session 5. The change in pattern to positive humeral lag may account for both higher accuracy and lower variability in performance. However, this is a tenuous conclusion based on the fact that session 6 mirrors session 5 for performance even though overall humeral lag is not positive for session 6.

The data from this study places practitioners in the unenviable position of stressing non-essential variables to promote pattern change but also stressing a Focus of attention to promote retention of performance. Perhaps a compromise would be do offer Focus of attention but make certain that the information follows the natural sequence of development for the skill at hand.

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Table 1

Standardized discriminant function for Condition

	Function		
	1	2	3
Humlag	-.100	.434	1.033
Forelag	.944	-.027	.683
handlag	.524	.902	-.134

Structure matrix coefficients for Condition

	Function		
	1	2	3
Forelag	.849(*)	-.452	.272
handlag	.279	.895(*)	-.349
Humlag	-.526	.415	.743(*)

Functions at Group Centriods for Condition

con	Function		
	1	2	3
1.00	.347	-.025	-.001
2.00	-.218	.004	-.015
3.00	-.335	-.012	.010
4.00	.172	.041	.004

Table 2

Standardized discriminant function for Session

	Function		
	1	2	3
Humlag	1.103	.243	-.139
Forelag	.307	1.118	-.154
handlag	.225	.384	.946

Structure matrix coefficients for Session

	Function		
	1	2	3
Humlag	.954(*)	-.278	-.114
Forelag	-.242	.918(*)	-.315
handlag	.101	.109	.989(*)

Functions at Group Centriods for Session

	Function		
ses	1	2	3
1.00	.160	-.007	.005
2.00	-.063	-.040	.014
3.00	.002	.028	.015
4.00	-.110	.018	.009
5.00	-.014	-.043	-.017
6.00	-.042	.028	-.023
7.00	.066	.017	-.003

Figure Caption

Figure 1- Target for determination of Radial Error.

Figure 2 – Humeral Lag by Condition and Session.

Figure *3* – Forearm Lag by Condition and Session.

Figure 4 – Hand Lag by Condition and Session.

Figure 5- Peak Velocities of Hand by Condition and Session.

Figure 6- Radial Error by Condition and Session.

Figure 7 –Variability of Radial Error by Condition and Session.

Figure 1

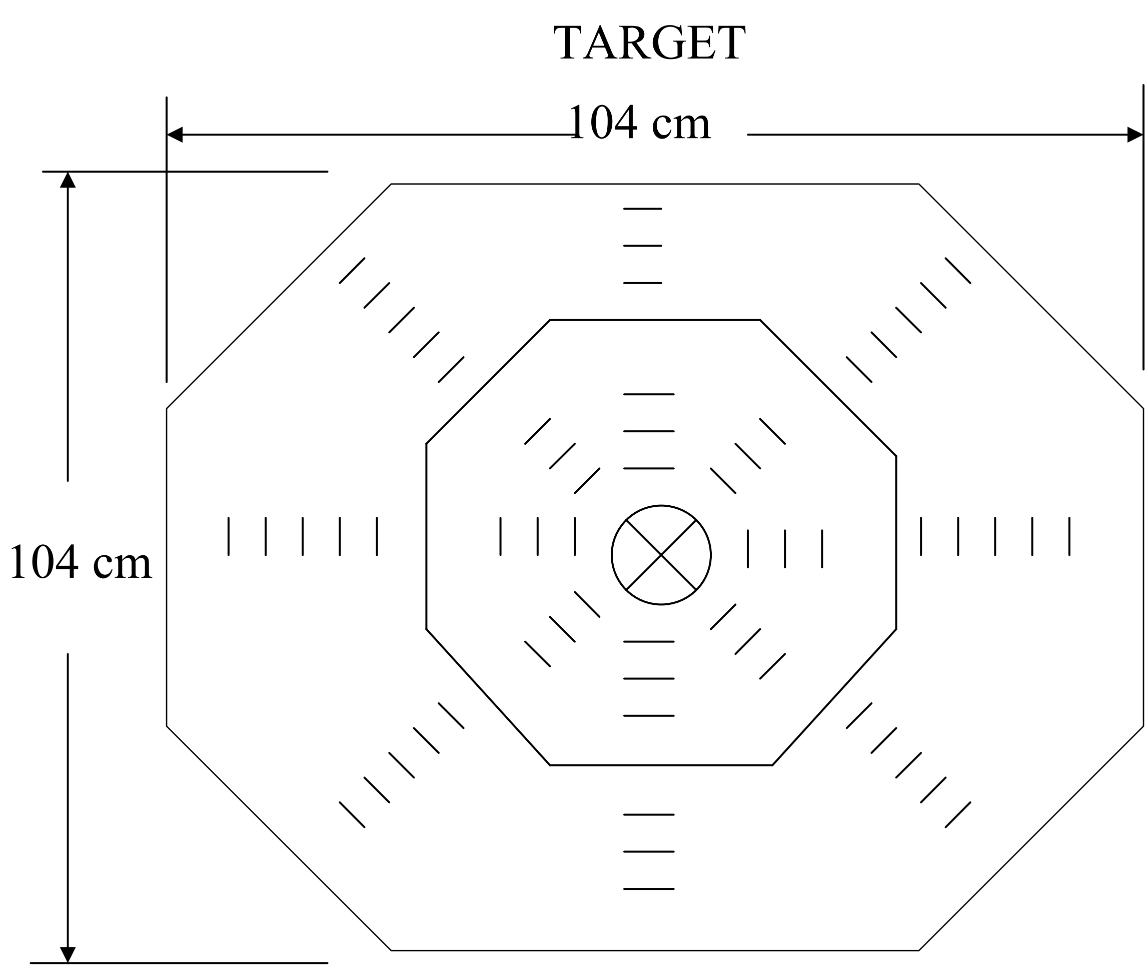


Figure 2

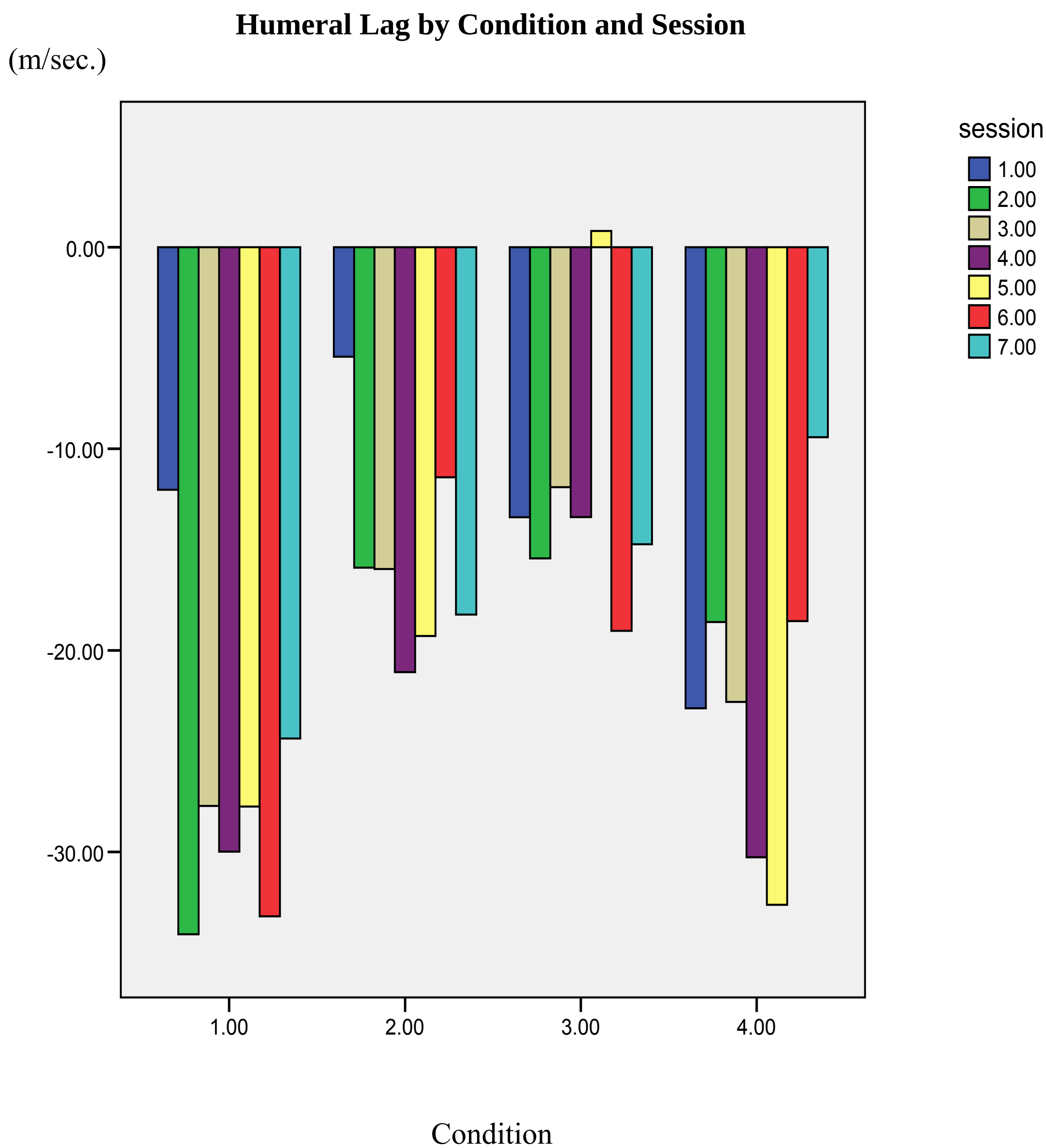

Humeral Lag by Condition and Session
(m/sec.)
0.00
-10.00
-20.00
-30.00
1.00
2.00
3.00
4.00
session
1.00
2.00
3.00
4.00
5.00
6.00
7.00
Condition

Figure 3

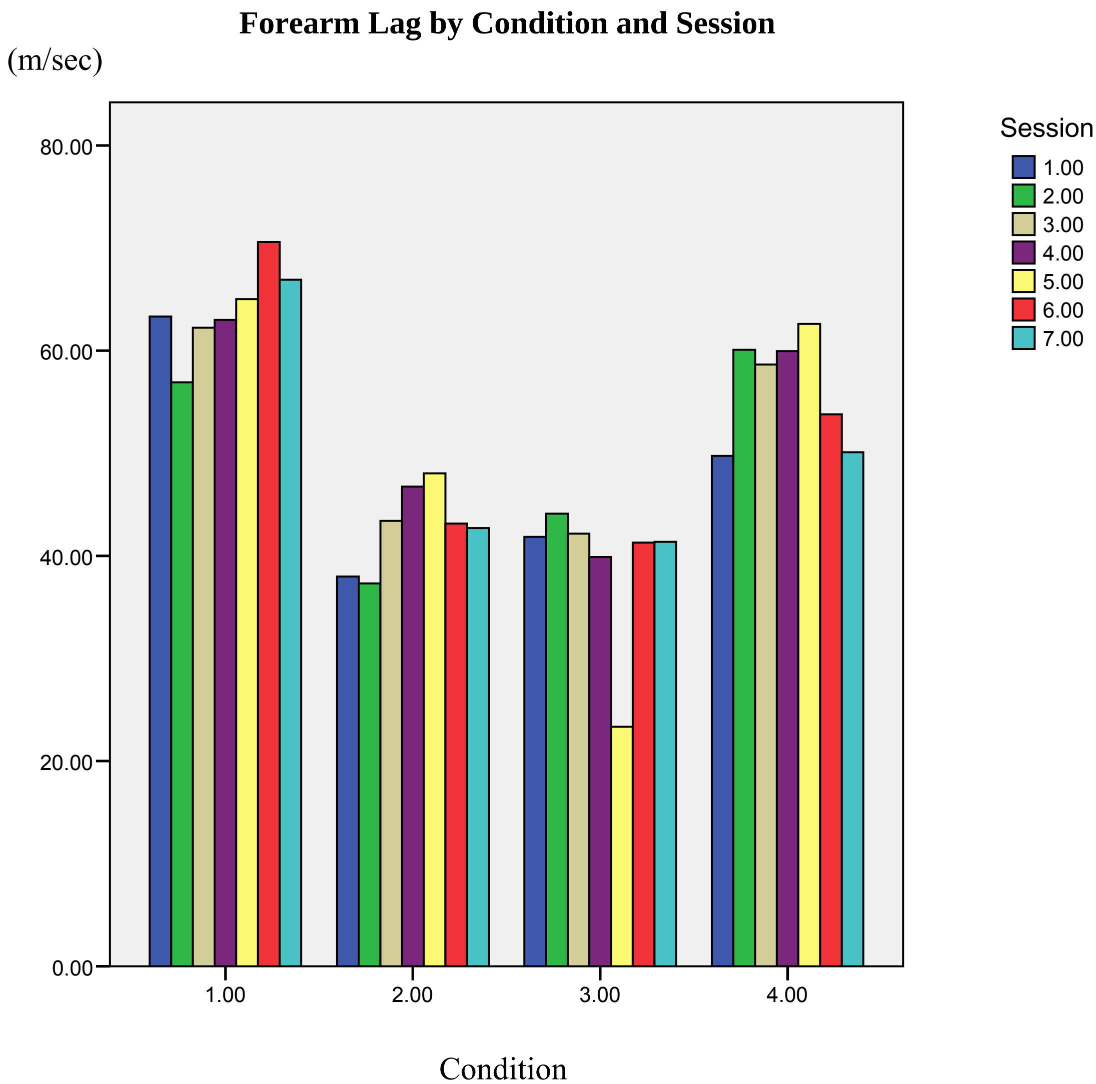

Forearm Lag by Condition and Session
(m/sec)
80.00
60.00
40.00
20.00
0.00
1.00
2.00
3.00
4.00
Condition
Session
1.00
2.00
3.00
4.00
5.00
6.00
7.00

Figure 4

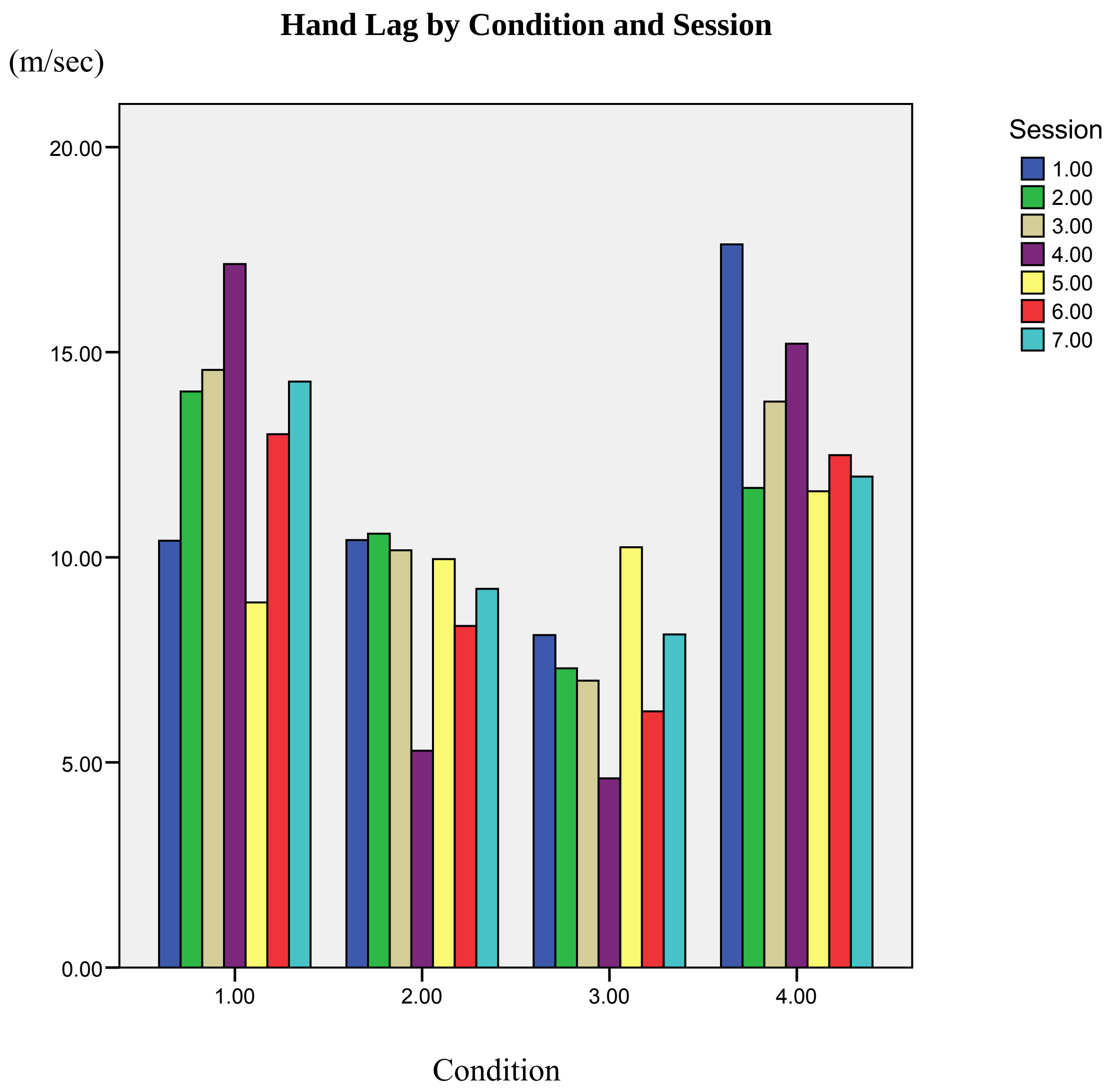
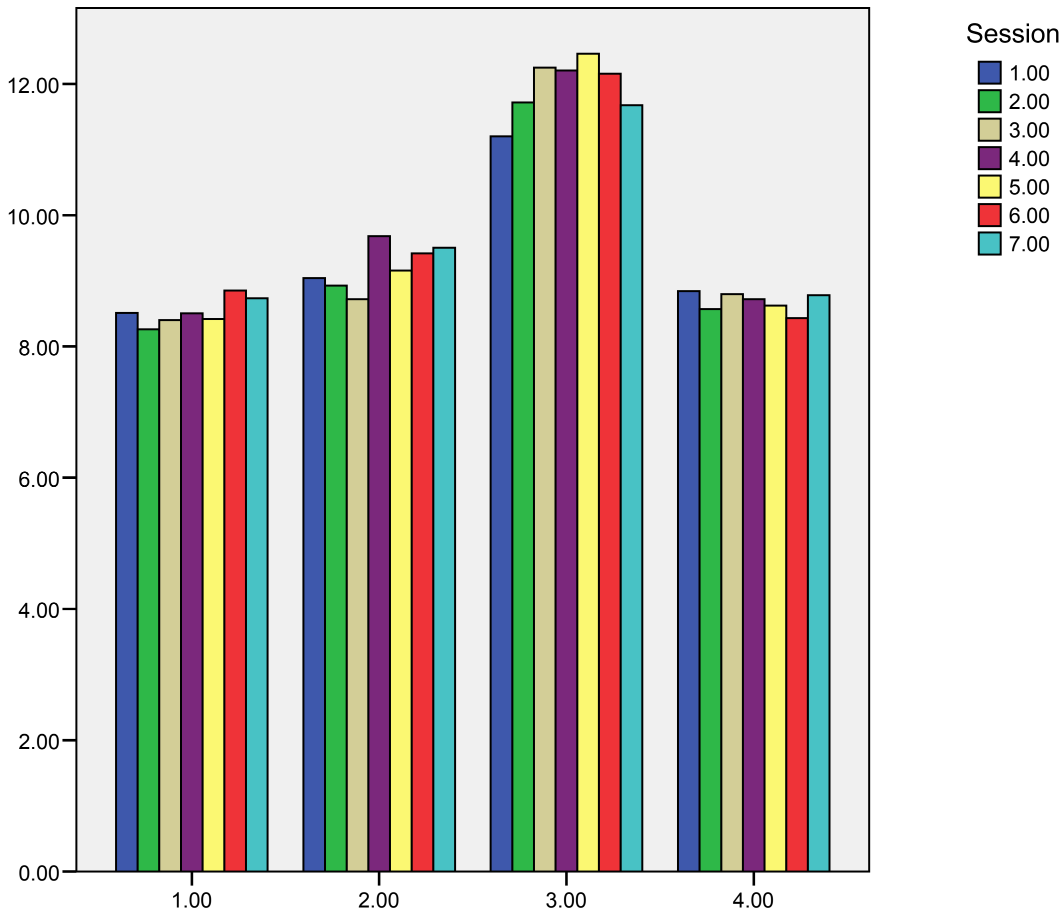

Hand Lag by Condition and Session
(m/sec)
20.00
15.00
10.00
5.00
0.00
1.00
2.00
3.00
4.00
Condition
Session
1.00
2.00
3.00
4.00
5.00
6.00
7.00

Figure 5

Peak Velocities of Hand by Condition and Session

(m/sec)



Condition

Figure 6

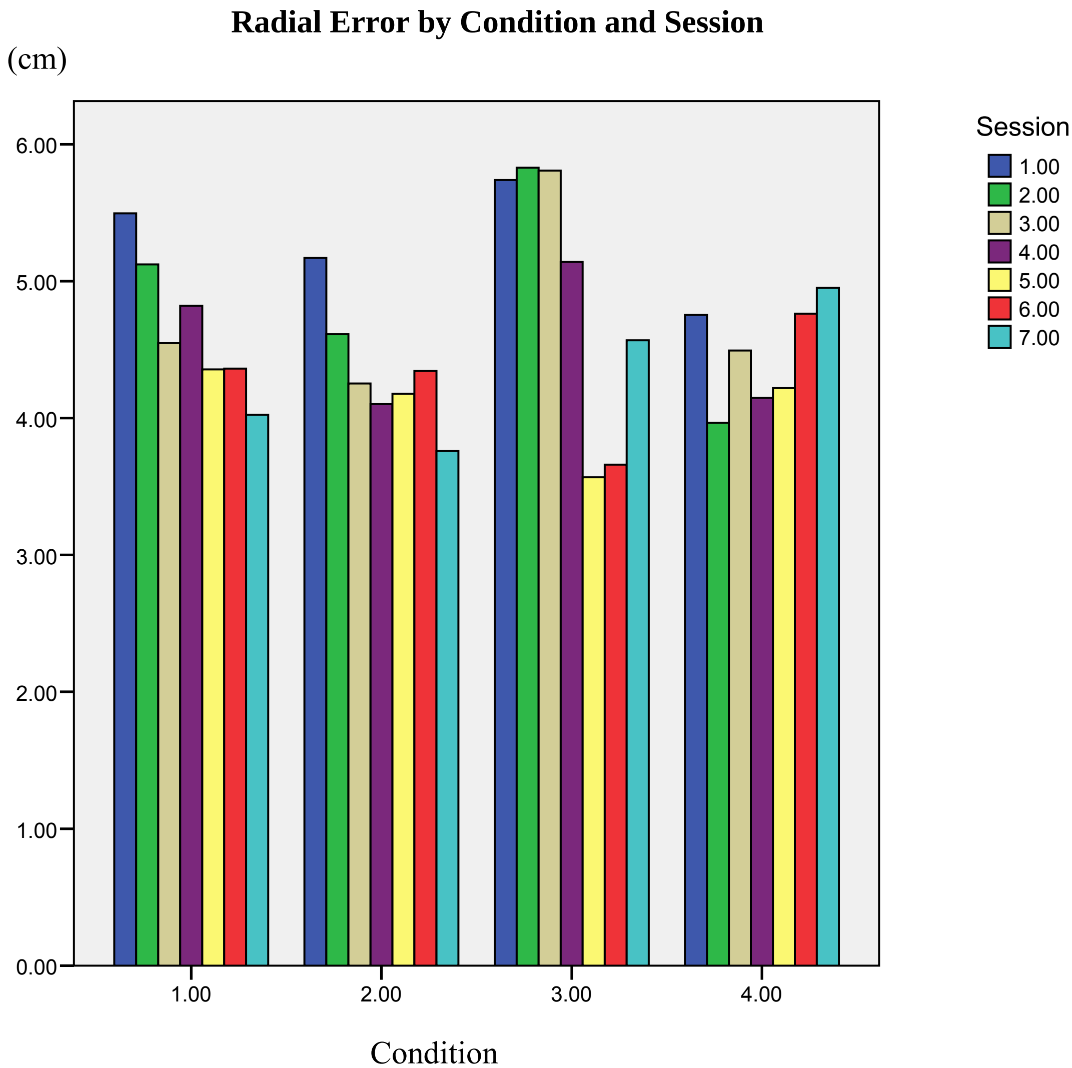
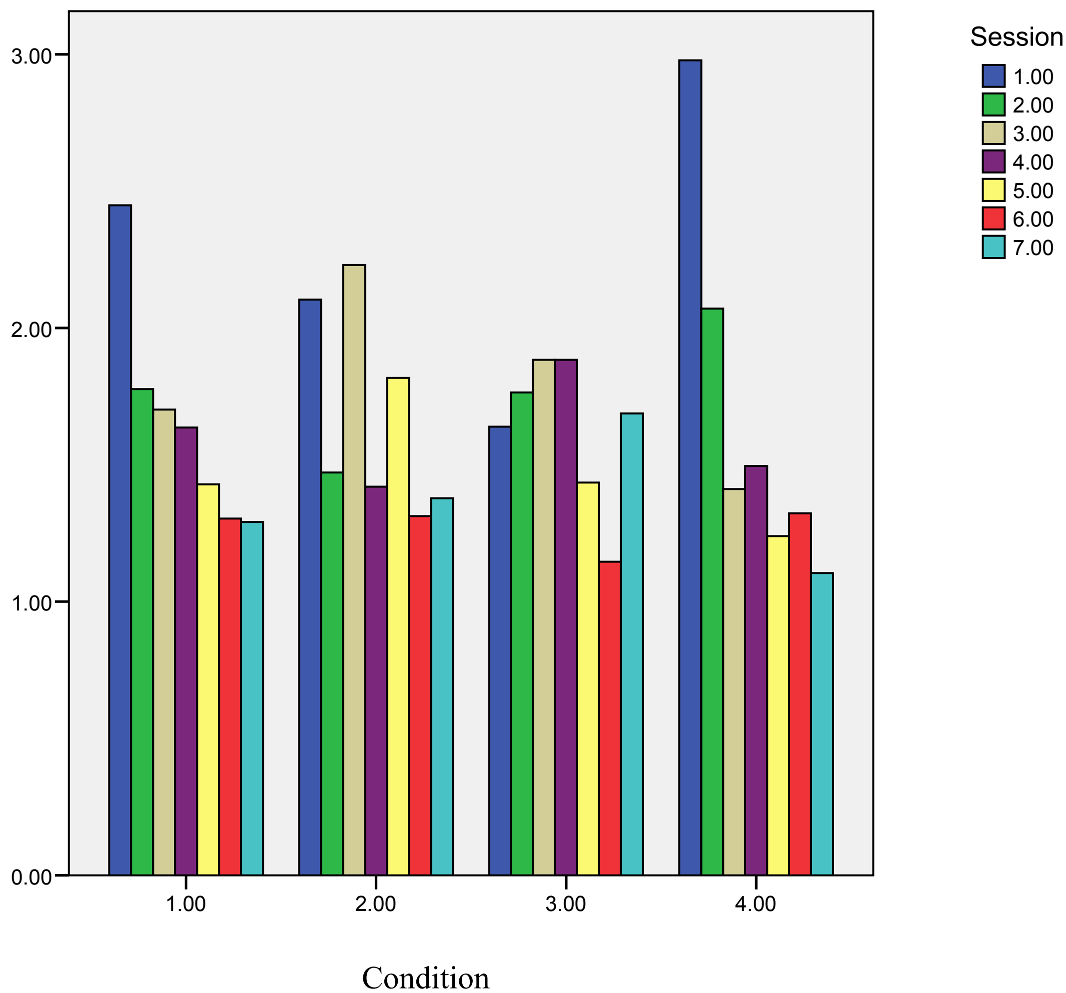

Radial Error by Condition and Session
(cm)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1.00
2.00
3.00
4.00
Condition
Session
1.00
2.00
3.00
4.00
5.00
6.00
7.00

Figure 7

Coefficient of Variance of Radial Error

By Condition and Session



ABSTRACT

Pattern Change and Performance: Focus of Attention and Control Parameter

By Nitin Jain, M.S., 2008

Department of Kinesiology

Texas Christian University

Thesis Advisor: Dan Southard, Ph.D.

The purposes of this study were to compare changes in motor pattern and performance of individuals when utilizing internal, external, or dynamic system perspective when learning the fundamental skill of throwing. Forty right hand dominant college age students (18-25 years) participated in this study. Participants were required to throw a baseball size ball to a target with their non-dominant limb. Participants were randomly placed into four conditions. Condition 1 was Internal Focus condition. Participants in this condition received the following instruction: 1) "turn so your right shoulder is closer to the mat", 2) when throwing shift your weight from back leg to front leg, and 3) "arch your back and first accelerate the trunk, then shoulder, then upper arm, and finally your hand". Condition 2 was the External Focus condition. Participants in this condition received the following instructions: 1) "turn sideways so you are facing the south wall", 2) when throwing shift your weight toward the mat, and 3) "throw the ball as if your trunk and arm were like a whip, like a horseman driving his horses". Condition 3 was the Control Parameter condition. Participants in this condition were encouraged to scale up on the control parameter of throwing velocity. Participants in the control parameter

condition did not receive any additional augmented information. Condition 4 was Control condition. Participants in this condition did not receive any augmented information nor they scale up on the control parameter. Participants were initially provided instructions and demonstration prior to the first trial. Augmented information was then provided after every 5th throw during practice sessions. The Focus and Control conditions were required to throw the ball at a preferred velocity. Participants practiced twice per week for three weeks for a total of 6 sessions. The seventh session was 10 days after the 6^{th} session. Participants were not provided any information during the 7th retention session. Accuracy of throw related to a target center was recorded for each trial. Two cameras were used to capture the throwing motion. A Peak Motion analysis system used to capture and analyze data. A 2-way (4 x 7) Multivariate analysis of variance (MANVOA) was completed on the three dependent measures of segmental lag (Humerus-Trunk, Forearm-Humerus, and Hand-Forearm). MANOVA was followed by Discriminant Function Analysis (DFA) in order to identify significant functions related to the significant MANOVA. Univariate analysis (ANOVA) was used to determine differences in identified functions by each independent factor. Scheffe post hoc analysis identified measures responsible for significant ANOVA. A two-way (conditions x sessions) ANOVA was completed to determine significant differences in radial error and coefficient of variation of radial error. An alpha level of .05 was selected for all statistical parameters. Results indicated that the control parameter and external focus groups were better instigating pattern change than other groups. The Focus groups demonstrated better performance accuracy over practice sessions. Focus groups also retained performance better than the control parameter and control group. It was concluded that scaling up on a control parameter and External Focus promote pattern change better than internal focus. Focus of Attention was better for retention of performance than the control parameter group.

APPENDIX 1

Consent Form

Project Title: Pattern change and Performance: Control parameter and Focus of attention.
Investigator: Nitin Jain

I,________________, hereby declare that I have been told by Nitin Jain, student in the Department of Kinesiology, about research concerning motor learning/behavior and its purpose. I have been told about the procedures to be followed. I understand the possible discomforts, risks, and possible benefits related 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 in the project at any time without prejudice to me.

I hereby freely consent to take part in this study.

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Signature of the participants Date

If you have any questions at any time concerning this project, or your rights as a participant, please call Nitin Jain (817 503-3999) or Dr. Dan Southard (817-257-6749), Supervising Professor, or Dr. Rhea (817-257-6861), Chairperson, Human Safeguard Committee Department of Kinesiology.

APPENDIX 2

Written Summary

This experiment is design to help movement scientists better understand the factors that contributing to the changing of motor skills to a more mature pattern. 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 basecall-size ball (using your non-preferred throwing arm) at a padded mat located five meters in front of you. You should try to hit the ‘X’ mark on the center of the mat. Accuracy will be recorded. Before collecting data, you will warm up with shoulder stretching exercises and performing five practice throws at preferred velocity. You will come to Motor Behavior Laboratory for six 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 that will also consist of 15 trials. There is minimal risk of muscle strain that could occur during trials. If you notice any pain or discomfort while performing trials, let me know immediately and i will discontinue the data collection. Should you need medical attention, beyond immediate first aid, 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 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 participants, It is my opinion that participant understands the risks, benefits and obligations involved with this project.

____

Investigator