2009

Focus of attention on movement technique acquisition of a Pilates roll-up

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FOCUS OF ATTENTION ON MOVEMENT TECHNIQUE

ACQUISITON OF A PILATES ROLL-UP

by

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Bachelor of Science
Western Washington University
2007

A thesis submitted in partial fulfillment
of the requirements for the

Master of Science Degree in Kinesiology
Department of Kinesiology and Nutrition Sciences
School of Allied Health Sciences
Division of Health Sciences

Graduate College
University of Nevada, Las Vegas
December 2009

THE GRADUATE COLLEGE

We recommend that the thesis prepared under our supervision by

Kristine M. Bragg

entitled

Focus of Attention on Movement Technique Acquisition of a Pilates Roll-Up

be accepted in partial fulfillment of the requirements for the degree of

Master of Science
Kinesiology

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December 2009

ABSTRACT

Focus of Attention on Movement Technique
Acquisition of a Pilates Roll-up

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Focus of attention manipulation has been shown to have an effect on learning and performance of movement tasks. The purpose of this experiment was to determine whether inducing an external or internal focus of attention while learning a Pilates roll-up had an effect on movement technique acquisition. Movement form, movement time, and distance reached served as dependent variables. Participants (n=22) were assigned to either an external or internal focus group and verbally instructed through 2 sets of 6 repetitions of the roll-up per day over two practice days. A retention test on Day 3 consisting of 2 sets of 6 repetitions without instructions demonstrated the permanent effects of learning and produced no significant group differences. Further research is needed to establish a relationship between focus of attention and complex skill learning in which movement form is emphasized in execution.

ACKNOWLEDGEMENTS

I would like to thank my committee and my raters for their time and patience, my family for always listening, and everyone at ET for allowing me to be defined by more than academic achievement.

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CHAPTER 1

INTRODUCTION

Human movement performance is affected by both physical capacity and mental strategy (Schmidt & Wrisberg, 2008; Wulf 2007a). Different fields of study ranging from medicine and science to art and leisure address the mental aspect contribution to successful movement outcome. Across this broad spectrum of literature, the research and scholarly opinions vary from one discipline to another. First, a variety of terms such as mental imagery, focus of attention and cognitive strategies act to define the method of mental engagement (Feldenkrais, 1972; Vernacchia, 2003; Singer, Lidor & Caraugh, 1993; Wulf). While much overlap occurs between the terms, there are limited conclusions to be drawn from the entirety of the research. A principle that can be agreed upon is the achievement of an ideal mind-set balanced between awareness and unawareness leading the ultimate goal of automaticity in motor skills (Singer et al., Vernacchia; Wulf, McNevin & Shea, 2001). However, where this mind-set occurs is a continued area of research.

Traditionally, it was thought that successful movement performance would result from paying attention to the movement itself, especially in beginners (Wulf, 2007b). Many physical activity instructors still teach with emphasis on “feeling the movement” and knowing how, when and where the body is placed throughout the activity (Feldenkrais, 1972; Franklin, 1996; Isacowitz, 2005; Pilates & Miller, 1945, Vernacchia, 2003). This is especially evident in activities with an artistic or technical component. The growing popularity of the body-mind connection in western culture gives heed to this type of practice.

Alternatively, in motor learning literature there is a well documented effect of adopting an external focus of attention to enhance in the learning and performance of a variety of motor skills (Wulf, 2007a). Using an external focus of attention requires the performer to focus on the effect of their movement in the environment, such as the swing of a club in golf, or the intended path of a basketball into a hoop. By removing attention to body mechanics, the performer relies on more automatic control processes to regulate force and neuromuscular coordination of the movement (Wulf et al., 2001). To date, nearly all studies on focus of attention have evaluated skills with a measureable, or quantitative, movement outcome. To make recommendations for focus of attention in activities with more reliance on technical components like gymnastics, diving or dancing, further research is warranted.

Purpose of the Study

The purpose of this study was to determine whether inducing an internal or external focus of attention while learning a Pilates roll-up has an effect on movement technique acquisition. Specific components of form were evaluated along with overall movement quality, movement time and range of motion.

Definition of Terms

Attentional cue

Prescriptive feedback that directs learners' attention to the most pertinent information for correcting a particular performance error.

Body-mind interaction

The relationship between cognitive thought processes and body function.

Constrained action hypothesis

Attention focused directly on the movement (internal focus) constrains the motor system. Conversely, attention directed to the movement effect (external focus) promotes the utilization of automatic control processes.

Direct imagery

The act of visualizing anatomical relationships of muscle and bone alignment.

External focus

A focus of attention that is directed to the outside of the body, specifically on the effect or outcome of the movement.

Feldenkrais Method

A system of mental and physical exercises designed to explore the kinesthetic awareness, or direct feel, of movement.

Indirect imagery

The act of visualizing an inanimate object such as a bouncing ball or floating leaf.

Internal focus

A focus of attention directed at one's body movement.

Kinesthetic

Sensory information about movement that comes from receptors in the muscles and joints.

Pilates Method

A series of exercises used to increase components of fitness such as strength, flexibility and balance.

Somatic education

A system of mental and physical exercises designed to explore the kinesthetic awareness, or direct feel, of movement.

Transfer of learning

The gain or loss of a person’s proficiency on one task as a result of previous practice or experiences on another task.

CHAPTER 2

LITERATURE REVIEW

Body-Mind Concept

The existence of a relationship between cognitive processes and their effect on the function of the body are referred to as the body-mind interaction. This concept has been present for centuries, and is currently recognized and under continuing research in psychology, neuroscience, medicine and physical activity (Pilates & Miller, 1945; Tan, 2007; Vernacchia, 2003). The overlying consensus is that through mental strategies, such as imagery and focus of attention, one can, to a degree, control or cause changes in bodily processes. In the field of physical activity, body-mind training is implemented by athletes, artists and physical therapists for overall performance enhancement. The following sections will discuss elements of mind-body practices directly related to physical activity.

Sport Psychology

Sports psychologist Ralph Vernacchia (2003) discusses three stages of concentration in physical activity processes. The first stage, decision making, occurs before movement initiation and acts to mentally prepare the individual for the upcoming task. This includes assessing the proper level and direction of attention to aid in decision making and alertness during the movement. Next, during the performance stage, the athlete is directed to achieve body-mind awareness through a generation of internal focus on the physical feel of the performance. Emphasis is placed on total awareness of movement feeling. Vernacchia says that kinesthetic awareness aids in confidence. The third stage of concentration, the evaluation stage, consists of assessing strategies used during performance and refinement for the future.

Feldenkrais Method

The Feldenkrais Method (FM) of somatic education is a system of mental and physical exercises designed to explore the kinesthetic awareness, or direct feel, of movement (Feldenkrais, 1972). The theory behind FM states that normal functioning and regulation of muscular movement are disrupted by activities of daily living. Feldenkrais believed declines in motor skills occur as a result of losing touch with the mental control of movements. Practice of FM aims to reeducate kinesthetic sense by attending to internal aspects of movement and enhanced body awareness. Individuals who practice FM are, in part, verbally guided through a series of movement exercises that direct their attention to muscle tone, skeletal alignment and intended course of movement actions (Buchanan & Ulrich, 2001). Feldenkrais referred to this as "awareness through movement," or ATM method. To test the effect of FM on improving movement capability, Dunn and Rogers (2000) measured distance reached during a hurdler's stretch before and after an ATM exercise. Twelve participants were given an imagery task to imagine a bristle brush gliding over the left side of the body. According to FM, participants would be expected to feel lighter and longer on their left side, and to reach farther in the stretch post-imagery versus pre-imagery. Eight out of 12 participants reported feeling "lighter" and "longer" on the left side of the body postimagery, and 10 of the 12 participants reached significantly farther on the side they perceived to be longer. However, this indicates that the two participants who felt the right side of the body was lighter and longer also reached significantly farther on the right side. The authors neither reported data nor made comment regarding right side results. Therefore, this experiment provided weak evidence for the effect of FM on distance reached due to the limited nature of statistical analysis and discussion, as well as a small sample size and no reported control measurement.

In a commentary by Ives (2003), the author argued against scientific credibility of FM through conflicting experimental results, inappropriate comparisons and uncontrolled study designs (Kolt & McConville, 2000; Bearman & Shafarman, 1999). Ives noted the effects were likely psychological and not physiological and provided evidence for a "nonawareness" approach to motor skill learning as presented by Singer et al. (1993). The effectiveness of kinesthetic training is still debated, but practiced in hundreds of private clinics internationally (The Feldenkrais Educational Foundation of North America).

Imagery in Dance

The Feldenkrais Method is practiced by contemporary dancers in forms such as ballet and modern dance to enhance performance through body awareness (Fortin, Long, & Lord, 2002). The Flak project, a collaborative research study in dance education, followed 12 hours of contemporary dance classes in a professional setting. Each class incorporated a FM segment designed to aid in transfer of learning and movement awareness facilitation. This exploratory movement session dealt with sensorimotor experiences such as curving of the spine, feeling weight through the feet and imagining anatomical relationships within the body. Emphasis was placed on finite awareness of movement and sensations felt as well as personal theories and experiences of the instructors. Students were encouraged to discover differences in the subtleties of each movement and expected to gain a heightened sense of correct movement patterns. No evaluation of effectiveness of the included exercises was given, nevertheless researchers suggest following the specific examples provided in the study to incorporate self-awareness practice in the dance culture.

Further examples of practices to cultivate the mind-body relationship are found throughout dance literature. In a text devoted to the various uses of imagery in dance, Franklin (1996) begins his discussion with the importance of intention in creating movement. He directs the dancer to "focus on [the] body part with the intention of moving it." The use of images directs ones focus to the intention of the movement and results in a clearer outcome. According to Minton (2003), images are pictures created in the mind and can be direct or indirect. A direct image involves visualizing anatomical relationships of muscle and bone alignment, and an indirect image refers to imagining an inanimate object such as a bouncing ball or floating leaf. The purpose of dance imagery is to create awareness of the feel of the movement. Minton and Franklin use the term body-mind awareness and claim connecting the body and mind teaches the dancer to be conscious of changes in alignment and muscle tension over time.

Pilates Method

The Pilates method is a common training tool used by ballet and modern dancers. The success of Pilates in the dance population is credited to the direct application of Pilates principles to dance performance through body awareness education. The method is a series of exercises used to increase components of fitness such as strength, flexibility and balance. The practice includes mat and specialized equipment exercises, often incorporating the use of modalities such as Therabands and inflatable therapy balls.

According to Balanced Body University, Inc. (2007), the number of Americans engaging in Pilates practice increased from 1.7 million in the year 2000 to 10.6 million in the year 2006.

The developer, Joseph Pilates, was a trained boxer and gymnast who also studied yoga and meditation while growing up in Germany at the turn of the 20th century. Pilates himself had no formal education in exercise science and has made claims that his exercises, "guard against unnecessary pounding or throbbing of your heart," and practitioners will develop, "perfect posture" (Pilates & Miller, 1945). Although lacking scientific basis in its development, Pilates has been adapted into clinical use for physical therapy and rehabilitation (Keays, Harris, Lucyshyn & MacIntyre, 2008). According to leading educators in Pilates today, the practice of Pilates should follow a set of guiding principles. While Pilates himself never published an official set of principles, modern Pilates schools derive their movement principles from suggestions of Pilates' main work, *Return to Life through Contrology* (1945). In this manuscript, Pilates discusses a direct connection between the health of the body and the health of the mind. He emphasizes the importance of proper breathing, uniform muscle development, and especially concentration to correct movement pattern. The concluding sentence of his work reiterates this teaching with the statement, "be certain that you have your entire body under complete mental control."

Isacowitz (2006) describes the Pilates method as introspective and discusses the significance of the mind, body, spirit connection. One of the outlined principles of Pilates practice according to Isacowitz is to "concentrate deeply." Through proper movement preparation and focusing on a particular muscle prior to the action, one will motivate accurate and more intense firing of the muscle than if not thought about at all. This statement is comparable to Herman (2007), who has included control, precision, and body awareness as three of her main principles of Pilates practice. For control, she advises students to give attention to detail of their movement. For precision, the student must know where each movement starts and ends. Under these terms, control and precision refer to internal focus conditions, and the third, body awareness, directly denotes introspection as well. Romana Kryzanowska, an original student of Joseph Pilates also considers concentration and control as two of her six principles (Gallagher & Kryzanowska, 1999). Her philosophy suggests that physical activity without complete control of the mind leads to disorganized, counterproductive movement.

The widespread view in the Pilates practice is that one must be completely conscious of their body to practice movements correctly and ultimately achieve movement automaticity. Without scientific evidence to support these claims, Pilates-based teachings should be considered only on a theoretical basis. Recently, Pilates has gained interest in the field of scholarly research. Bernardo (2006) conducted a literature review of published research on Pilates in healthy adults. She located 39 articles in peer-reviewed journals among which included just 3 clinical trials. Within these trials, the author cited a lack of true experimental designs and small sample sizes. Due to the lack of sound research in the field, Bernardo concluded a need for research in Pilates.

In the past two years, further research has been performed primarily in the areas of exercise physiology, biomechanics and physical rehabilitation (Keays et al., 2008; Lynch, Chalmers, Knutzen & Martin, 2009). Shedden and Kravitz (2007) suggest a stronger support of Pilates' benefits in the literature, citing studies in motor control, range of motion, body composition, injury rehabilitation and progressive overload. While the research topics appear to have expanded, the efficacy of Pilates in specific contexts, such as motor control, are still limited.

Lange, Unnitham, Larkam and Latta (2000) published a review to summarize the claims made on the effectiveness of Pilates-inspired exercises in motor learning. Leading sources (Balanced Body, Inc., 2007; Merrithew Corporation, 2009) contend that Pilates leads to enhanced core control, balance, posture, coordination and aesthetically pleasing movement form. Clinical studies to examine these effects is limited and of mixed results. In a study of low back pain and postural enhancement, improvement was observed with combinations of Pilates alone or with added postural and relaxation exercises (Curnow, Cobbin, Wyndham & Choy, 2009). However, no significant difference between experimental groups was established and results of a one-legged standing test were reported unreliable. Asymptomatic females training in Pilates demonstrated better transverse abdominal isolation over the abdominal curl and control experimental groups after a six month period in a separate study (Herrington & Davies, 2005). The Pilates participants passed the TrA isolation test at a rate of 93% versus 33% in the abdominal curl group and 25% in the control group. Conversely, isokinetic evaluation of trunk flexors (abdominals) and extensors revealed only a slight but significant increase in total work performed (10%) by flexors after 12 weeks of training. As observed by the dissimilarity in results of the existing literature, it is naïve to claim of Pilates exercise contributes to enhanced movement form.

Lange et al. (2000) continued their review with recommendations to facilitate the motor learning process in Pilates by means of concepts addressed in motor learning literature. Discussion included frequency and specificity of augmented verbal feedback, recognizing the learning performance distinction and variation in the ordering of practice trials (contextual interference). In particular, when giving verbal feedback it was advised to direct focus to internal body sensations. An example was to "funnel ribs to pelvic bowl." Currently, no controlled experimental studies exist that investigate focus of attention to body awareness and enhanced movement in Pilates. Still, the methodology continues to be used in practice of the performing arts, therapy and fitness training. A review of the motor learning literature in sport provides numerous examples of focus of attention and its effect on movement learning and performance. The following section will discuss the effects of external focus of attention, a concept missing from the body-mind teachings.

Focus of Attention

Motor learning literature identifies two types of attentional focus: internal and external (Wulf, 2007b). An internal focus of attention directs ones thoughts to their body, or on the movement itself. An external focus of attention directs thoughts outside of the body, or on the effect of the movement. Focus of attention may vary according to the nature of the task and the performer's level of expertise. The following sections will discuss focus of attention as is applies to different motor skill situations.

Wulf, Höβ & Prinz (1998, Experiment 1) placed subjects on a ski-simulator apparatus or a stabilometer (1998, Experiment 2) with instructions that induced either an internal or external focus of attention. A ski-simulator consists of a platform attached to two rails by a set of wheels. When the subject exerts force to either side of the platform, it will begin to slide down the ramp until the participant's weight is shifted and the platform glides in the opposite direction. While performing the ski-simulator task (Wulf et al., Experiment 1), participants in the internal focus group were instructed to push on the platform with the outer foot and focus on that foot. Participants in the external focus group were instructed to focus on the wheels underneath the platform while sliding back and forth. The actual distance between the participant's foot and the wheels measured only about an inch, but after two days of practice, the external focus group produced significantly larger amplitudes and showed greater improvement in learning over the internal focus group. On the day three retention test with no attentional focus instructions, the external focus group again produced larger amplitudes over the internal focus group, demonstrating the more permanent learning effects of the skill. In the second experiment (Wulf et al., Experiment 2), similar findings resulted in the case of the stabilometer. While standing on the stabilometer, or balance platform, the goal is to hold the platform horizontal by applying equal weight in each foot. For this task, internal focus instructions directed subjects to focus on their feet, while the external focus instructions directed subjects to focus on small green markers placed on the platform just in front of their feet. On practice trials during Days 1 and 2, there were no notable differences in balance performance. On the Day 3 retention test when instructions were removed, the external focus group performed with a smaller degree of error than the internal focus group.

To test the effects of focus of attention in the field, Wulf, Lauterbach and Toole (1999) selected a golf task. Each participant (n = 20) performed a pitch shot to a target with a diameter of 90 cm placed at a distance of 15 m away from where the participant was standing. Performance was measured by a score assigned to different regions within the target. Experimental groups consisted of an internal focus group, which received instructions to focus on their arms, and an external focus group, which received instructions to focus on the club while swinging. The external focus group scored higher across all 80 practice trials with reminders of where to focus attention as well as on 30 retention trials with no focus of attention instructions. Experimental evidence for the external focus advantage now existed for sport skill application with sufficient support to continue observing the focus of attention effect.

Level of Performer

The effect of instructions given to performers who are in the beginning stages of learning a movement task differs from those who are well-practiced, or experts, at the task. It was therefore necessary to further examine the possible effect of focus of attention instructions on individuals of varied skill levels. In a study of high and low skilled golfers, the findings of Perkins-Ceccato, Passmore and Lee (2003) suggest that internal focus instructions are more advantageous to the low skilled golfer, while external focus instructions are advantageous to the high skilled golfers. This effect was observed only in the variable error outcome measure, demonstrating performance consistency from shot to shot, but not in average error, which represents shot accuracy. Any observed effect of average error may have been lost due to the ordering of attentional focus conditions. Each participant was presented with both focus conditions, and this may have caused a carryover effect from the initial instructions to the subsequent condition. Additionally, the instructions given under the internal focus condition lacked specificity about which aspect of the skill to focus on. The internal focus instructions directed participants to “concentrate on the form of the golf swing and to adjust the force of their swing depending on the distance of the shot." This may have lead to varied interpretation with the possibility that individuals focused on the club while attending to the force of the swing and not to their bodily production of force. In this case, participants could have been implementing external focus techniques under the internal focus condition.

As a follow-up to Wulf et al. (1999), Wulf and Su (2007) repeated their initial study of golf pitch shots in novice golfers with the addition of a control group to measure participants' performance when left to their own devices. As observed previously, the external focus group achieved greater accuracy than the internal focus. The performance of the internal focus group was similar to the control group, demonstrating the enhanced learning effect of external focus over internal focus and natural focus tendencies (control).

Constrained Action Hypothesis

To explain the observed advantage of external focus, Wulf, McNevin and Shea (2001) proposed the constrained action hypothesis. The hypothesis proposes that attention focused directly on the movement (internal focus) constrains the motor system. Conversely, attention directed to the movement effect (external focus) facilitates the utilization of available automatic control processes. The motor system operates through a series of reflexive control mechanisms lying in the spinal cord and brainstem (Schmidt and Wrisberg, 2008). The monosynaptic (M1) stretch reflex operates involuntarily such as in control of postural sway because it travels the shortest distance up the spinal cord. In reactions with a longer latency between stimulus and response, the higher order of reflex is used. This allows more opportunity for voluntary or conscious contribution to movement. According to constrained-action hypothesis, external focus enhances coordination by removing conscious awareness to movement and permitting a greater degree of reflexive control.

To test the constrained-action hypothesis Wulf et al. (2001) designed an experiment similar to Wulf et al. (1998) using the stabilometer for a dynamic balance task assigning participants to either internal or external focus conditions. As supported by previous research their experiment reported smaller errors (i.e. better performance) for the external focus group than the internal focus group. The frequency of movement adjustments was also higher in the external focus group. The frequency of adjustments reflect the level of involuntary, reflexive control being utilized. A higher frequency of adjustments indicates higher automaticity and less conscious interference with the movement. Additionally, probe reaction time (RT) measured attentional demands through integration of a secondary task. The external focus condition demonstrated lowered probe RTs, suggesting a higher level of attention was available to the secondary task as a result of less conscience interference on the primary task.

Constrained action hypothesis also indicates that a certain level of task difficulty must be present for the external advantage effect to emerge. Therefore, tasks that are already highly automated will not gain additional benefit from external focus, as there is minimal, if any, voluntary control contribution. Evidence from Wulf, Töllner and Shea (2007) demonstrates this effect through a two-part experiment involving balance tasks performed on a flat, metal force plate (solid surface), foam mat on top of the force plate, or a rubber disk on the force plate. While standing on the solid surface, no significant difference was observed between focus of attention conditions. On the foam surface, participants had a higher magnitude of sway than while standing on the solid surface. Simple main effects for the foam surface yielded a significant difference between external focus and control groups, but found no significant difference between internal focus and control or internal focus and external focus. Under the third and most unstable condition of the experiment, the rubber disk, the effect of external focus emerged with greater postural stability achieved under external focus compared to both internal focus and control conditions.

While standing on the more compliant surfaces (solid and foam), there was little opportunity for voluntary control mechanisms to contribute to balance. As the support surface decreased in stability and higher reflexive control was warranted, the external focus condition proved advantageous by limiting voluntary contribution to movement as postulated by the constrained-action hypothesis.

EMG and Kinematics

Additional observations of the external focus advantage have been documented across varied participant skill levels in both complex motor tasks and sport skill situations such as dart throwing (Marchant, Clough & Crawshaw, 2007), cycling on a pedalo (Totsika & Wulf, 2003), basketball free throws (Zachary, Wulf, Mercer & Bezodis, 2005), soccer chips (Uehara, Button & Davids, 2008) and volleyball serves (Wulf, McConnel, Gärtner & Schwarz, 2002). Aside from measuring task outcome variables as noted in these studies, the external focus advantage has been studied on the neuromuscular level through electromyography (EMG) and in kinematic measures of force production and joint torque.

Vance, Wulf, Töllner, McNevin, and Mercer (2004) measured EMG in the biceps and triceps while participants performed a biceps curl with a curl bar in a within subjects study design. Four sets of biceps curls were counterbalanced under the two experimental conditions, focusing either on their arms (internal focus) or on the curl bar (external focus). In Experiment 1, biceps curls were performed significantly faster under the external focus condition with an average angular velocity of 76.7 °/sec versus 82.2 °/sec for external and internal conditions, respectively. Although no instructions were given about movement speed, the present findings demonstrated that movements were unintentionally performed faster under the external condition. Measurements of integrated EMG (iEMG) represent EMG activity as a function of time. The iEMG results for the external condition were significantly lower in both biceps, and triceps. Because all trials required the same amount of weight to be lifted, the reduced iEMG under external focus shows the same amount of muscular activity was exerted with less effort than under internal focus. Thus, the observed results followed the notion that external focus would facilitate greater movement economy through lowered neuromuscular activity (Wulf et al., 2001). Even when movement time was controlled for in Experiment 2, the iEMG activity was still reduced under external focus conditions, but was only significant during the flexion phase.

In a task requiring maximal force production, Wulf, Zachary, Granados, and Dufek (2007) assigned participants to a jump-and-reach task using a Vertec instrument to measure height reached. In a within-participants design with control, external focus (rungs of the Vertec) and internal focus (fingers) conditions counterbalanced, the external focus group jumped significantly higher than the other two conditions. To establish cause for the observed effect, a second experiment tracked each participant's center of mass (COM) as they jumped under the same conditions. If the COM displacement was greater in the external focus condition, jump height could be attributed to greater force production and not left to question whether participants were production other effective actions, such as increasing joint angles. The COM displacement was greater for external focus (24.5 cm) than internal (23.2 cm), and the effect of focus condition was significant.

Further research examples combining EMG, maximum force production and movement accuracy have produced complimentary results. In a follow-up study of jump-and-reach height with the Vertec, Wulf and Dufek (2009) collected additional kinematic data to expand knowledge of the underlying sources contributing to the external focus advantage. Participants' jump height, center of mass displacement, jump impulse and lower extremity joint moments were all significantly greater while focusing externally. Also, in a force production task of isokinetic elbow flexion performed on a dynamometer, external focus resulted in higher peak net joint torque, lower peak EMG and lower mean integrated EMG (Marchant, Greig & Scott, 2008). Both studies demonstrate that the effect of directing one's attention to the movement outcome results in greater force production with less muscular activity. This suggests more efficient co-contraction and recruitment of muscles involved in the task. Zachry et al. (2005) found that external focus increased basketball free throw accuracy accompanied by decreased EMG activity in the shooting arm. The lowered EMG effect was significant for the biceps brachii (agonist) and triceps bracii (antagonist) but also produced a trend of decreased activity in the flexor carpi radialis and deltoid. Unlike Vance et al. (2004), where the participants were instructed to focus on the arm under internal conditions, Zachry et al. directed the shooters' attention to their wrist. The effect of lowered EMG in muscle groups not specifically instructed to focus on demonstrates a possible spreading effect of neuromuscular coordination throughout the motor system.

Qualitative Skill Acquisition

As observed in over a decade of research (see Wulf, 2007a), this decreased “noise” in the motor system has brought about beneficial effects of external focus in several aspects of movement learning and performance. The immediate learning effects have been observed for from the first day of practice to retention and transfer conditions as well as in displays of increased movement accuracy and maximum force production. These advantages are measurable against control conditions in addition to internal focus instruction. Still, a considerable shortcoming in the focus of attention research involves a lack of evaluation of tasks for which movement form is emphasized. Quantitative measures of speed, amplitude and accuracy are not determinants of movement success in all movement skills as they are for activities such as basketball or golf. In competitive athletics, gymnasts, divers and figure skaters are just a few examples of sports that are rated for success based on movement form. Also, dancers rely on specific technique to adhere to style parameters and delivery of a message or story in their composition.

One study of movement form and external focus feedback has been conducted using a volleyball task (Wulf et al., 2002, Experiment 1). Movement quality assessed in both novices and advanced players via expert rating resulted in no differences under internal and external focus of attention. Movement accuracy, as defined by points scored for hitting within a target range, was significantly increased for the external conditions. For the quantitative aspect of the skill (movement accuracy) the external focus advantage concurred with previous studies (Wulf et al., 1998; 1999; 2001; Zachry et al., 2005). The qualitative aspect (movement form) drew no conclusion as to an advantage of one focus of attention over another.

In a study of novices performing a soccer chip (Uehara et al., 2008) with the non-dominant foot over a barrier to a target, outcome measures of landing accuracy, consistency and qualitative movement form showed comparable improvement regardless of focus instructions. However, a shortcoming may have resulted from the wording of the instructions. As stated in the study, the internal focus instructions directed focus to participants' body parts. One movement cue said, "to plac[e] your right foot next to the side of the ball." Under external focus, the instructions were not as clear. The intention was to direct focus to movement outcome, but the cue made no reference to the actual goal of hitting the target. Participants' final instruction set suggested the ball be kicked, "as if passing…to another player." The event of kicking the ball towards a target may result in an entirely different movement pattern than kicking towards another player. Therefore, this set of external focus instructions cannot be evaluated as effective for this skill.

In a study with a juggling task, Zentgraf and Munzert (2009) measured differential effects of kinematics and ball trajectories between attentional focus conditions. Results here proved no further sound conclusions about the effect on movement form correctness. For the outcome variable of ball height, external focus was more successful, producing the least amount of height discrepancy between balls in flight. This would be an expected result of enhanced neuromuscular control and muscular co-contraction under external focus (Wulf et al., 2001). Conversely, analysis of body displacement indicated a benefit of internal focus. The least amount of elbow flexion and shoulder displacement occurred for the internal focus group, with the external focus and control groups performing similarly. Researchers suggested minimal body displacement reflected enhanced control as demonstrated by previous analysis of an expert juggler. It is difficult to conclude whether the smaller movements in novices were indicative of greater control as they were in the expert juggler. For a novice, lesser joint displacement could be a result of stiffer movement. Conscious attention to body mechanics may have shortened a naturally occurring range of motion for the beginners. After all, the goal of achieving smaller discrepancy in ball height was performed more successfully in the novice with external focus instructions.

A third measured factor, overall task correctness, as determined by three expert raters, found the effect of trial block significant, but no significant difference for the effect of group. The complexity of juggling and number of variables measured may have contributed to the inconsistent results. Furthermore, the main goal of the juggling task as well as volleyball (Wulf et al., 2002) and soccer (Uehara et al., 2008) involved object manipulation. To produce reliable evidence to the focus of attention effect on qualitative movement, the evaluated task needs to be one in which the main goal is proper movement technique. Continued investigation using movement activities with increased dependence on qualitative factors will provide more relevant results.

Summary

Pilates is not completely void of suggestions to induce an external focus of attention. During a roll-up skill, students may be instructed to "hold the reins of a horse" (Isacowitz, 2006) or to visualize picking-up a "strand of pearls" (Herman, 2007). More common cues involve a combination of internal and external reference points. Instructions to "not wear your shoulders as earrings" (Balanced Body, Inc., 2007) provide an external imagery, but still refer to segments of the body. In the currently reviewed Pilates sources, no acknowledgement of a difference between internal and external focus directions was given. Isacowitz (2005) has assigned four categories to movement cueing instruction: visual, auditory, experimental, and tactile. Under the auditory category, two sub-categories are listed: analytical and figurative. An analytical cue gives scientifically sound information, such as muscles used. A figurative cue uses images to provide a shortcut, or a quicker way to describe the movement. Isacowitz admits that for certain skills, no amount of his explaining seems to illustrate the purpose of the movement correctly. This demonstrates fundamental need for motor learning research to address the issue of where to direct attention while learning technical movement.

Without reliable literature, the performing art and body-mind exercise methods will continue to make recommendations based on personal theory. The purpose of the present experiment is to examine both internal and external focus of attention on movement for acquisition of a Pilates skill.

CHAPTER 3

METHODOLOGY

Participants

Twenty-two healthy adults (F = 13, M = 9) aged 18-31 years old were recruited from the Department of Kinesiology and Nutrition Sciences. Participants began by giving written informed consent acknowledging their understanding of the experiment and willingness to complete the study. None of the participants had previous routine experience with Pilates practice, nor motor impairments affecting normal movement skill acquisition. Participants attended testing on three separate days over a one week period.

Apparatus and Task

The Pilates roll-up exercise was performed on a standard 24” x 68” Pilates mat measuring ¼” thick to serve as a cushion between the participant and the tile flooring of the laboratory. The task required the participant to learn a roll-up with guided instructions. The roll-up begins with the participant lying supine with the arms extended to 180 degrees. The motion sequence proceeded as follows: arms rise above the head, followed by lifting of the head, shoulders and back until the participant is in a seated position with maximal flexion of the spine. The participant extends to an upright seated position and rolls back down, returning to the starting position.

All trials were recorded with a Sony HC62 video camera (60 Hz) and analyzed with Dartfish TeamPro software (v.4.0). The camera was placed 14 feet from the mat with a view of the participant’s left side. A colored marker was placed on the participant’s left pointer finger and left lateral malleolus for reference measurement.

Procedure

Participants were randomly assigned to the internal or external focus groups. On Day 1, all participants were recorded performing a seated forward reach with standardized form instruction for reference of baseline distance reached. All participants were then shown a video demonstration of the Pilates roll-up with explanation of the skill. They were next given a guided warm-up of 3 deep breaths followed by 10 abdominal crunches and 5 roll downs from a seated to lying position as modeled by a typical Pilates warm-up. Participants in the internal focus condition were given verbal cues that involved references to their body movements (see Table 1, top). The cues given to participants in the external focus group were similar, but body parts were not mentioned; instead, they involved analogies to provide the same information (see Table 1, bottom). Participants were instructed through 2 sets of 6 repetitions of the roll-up with a 90 -second break between sets. One instruction script repeated every other repetition to allow adequate information to be given. Day 2 proceeded with the same protocol as Day 1. After two days of practice, a retention test was conducted on Day 3 to assess any differential effects of the treatment conditions on learning. For retention testing, a warm-up was given, but there were no movement demonstrations or instructions. The participants performed 2 sets of 6 trials at their own pace. At the end of the experiment, participants were administered a short questionnaire regarding variables related to the task. Finally, participants were debriefed by the experimenter as to the instructional conditions and purpose of the study.

Table 1.

Verbal Instructions

<u>Internal Focus Instructions</u>

Think about your body placement to create a continuous, fluid motion

Inhale: Arms rise

Exhale: Roll up, curling your spine…reach past your feet

Inhale: Sit-up, hands in line with shoulders

Exhale: Roll down, legs stay straight

Inhale: Arms rise

Exhale: Roll up, chin lifted

Inhale: Sit up, press shoulders down

Exhale: Roll down

<u>External Focus Instructions</u>

Think about the images I am giving you to create a continuous, fluid motion

Inhale: Reach to the ceiling

Exhale: Roll-up like a banana peel…reach for the wall

Inhale: Sit up, still reaching for the wall

Exhale: Press into the floor, roll down

Inhale: Reach to the ceiling

Exhale: Roll up, tennis ball under your chin

Inhale: Sit up, waterfall down the back

Exhale: Roll down

Dependent Variables and Data Analysis

Movement form rating served as a measure of the quality of the movement. Two raters trained by the experimenter in the skill and scoring procedure rated the first and last repetition performed by all participants on each day for a total of six ratings per participant. Scores were determined by rating five elements of movement form on a numbered scale according to degree of correctness in form execution (see Table 2). Raters were blind to group assignment and experimental procedure.

Table 2.

Movement Form Rating System

Element 1:	**Spine curves one vertebra at a time**			
incorrect		partially correct		completely correct
1	2	3	4	5
Element 2:	**Shoulders are pressed down**			
incorrect		partially correct		completely correct
1	2	3	4	5
Element 3:	**Arms stay in proper alignment**			
incorrect		partially correct		completely correct
1	2	3	4	5
Element 4:	**Feet stay on the floor**			
incorrect		partially correct		completely correct
1	2	3	4	5
Element 5:	**Movement maintains a continuous flow**			
incorrect		partially correct		completely correct
1	2	3	4	5

Additionally, kinematic measures derived from the Dartfish software (v.4.0) were used as objective measures of movement time per repetition and distance reached while in flexion. Movement time was the total amount of time for one repetition of the roll-up to be completed. Start time was defined as the first frame with movement of the marker placed on the pointer finger followed by 5 consecutive frames of upward movement. End time was defined as the final frame of marker movement proceeded by at least 5 frames of downward movement. Distance reached was measured as the distance displaced on the horizontal axis between the markers on the pointer finger and the lateral malleolus. Distance reached was reported as the distance measured (cm) for each repetition minus the respective participants' baseline measurement from Day 1. A positive distance reached indicated reach beyond their respective baseline reach, and a negative distance reached indicated reach less than baseline.

An intraclass correlation coefficient for form scores of the two raters was performed as a measure of reliability. Form scores, as well as distance reached, were analyzed in a 2 (focus group) x 2 (day) x 2 (trial) ANOVA with repeated measures on the last two factors for the practice phase (Days 1 and 2), and a 2 (focus group) x 2 (trial) ANOVA with repeated measures on the last factor for the retention phase (Day 3). Movement time was analyzed in a 2 (focus group) x 2 (day) x 12 (trial) ANOVA with repeated measures on the last two factors, and a 2 (focus group) x 12 (trial) ANOVA with repeated measures on the last factor for the retention phase (Day 3).

CHAPTER 4

RESULTS

Reliability of Form Scores

An intraclass correlation coefficient of R = .752 was obtained for the two movement raters. An intraclass correlation coefficient measures the reliability of the mean test score for each participant (Baumgartner & Jackson, 1995). Further analysis of form scores on each trial was conducted by calculating a mean from the two rater's scores (Weeks, Borrousch, Bowen, Helper & Osterfoss, et al., 2005; Wulf et al. 2002).

Questionnaire Data

Participants reported on four variables related to the task upon completion of the study. The purpose of the questionnaire was to supplement the findings of the main dependent variables (movement time, distance reached and form scores). Each question was answered on a 10 point scale with a score of zero as low and a score of 10 as high. Means and standard deviations for questionnaire data are displayed below (Table 1). Participants were generally motivated to learn the task and indicated a high amount of attention paid to the instructions. However, despite receiving instructions without direct references to body segments, participants in the external group reported a high amount of attention to specific placement of the body. Attention to thoughts or images unrelated to the body was lower than attention to specific placement of the body for both groups. An independent t-test for Question 3 confirmed no significant difference between focus groups and the external focus manipulation, t (19) = 1.603, $p = .125$.

Table 3.

Post-performance Questionnaire Results

	External Group		Internal Group	
Question	*M*	*SD*	*M*	*SD*
1. How motivated were you to learn the roll-up task?	7.3	2.54	6.3	2.57
2. How much did you think about specific placement of your body?	8.1	2.23	8.3	1.03
3. How much did you think about images unrelated to your body?	5.1	3.21	3.2	2.23
4. How much did the instructions influence your thoughts?	8.3	1.64	7.8	1.66

Practice

Movement times

Movement times were measured for all trials for each participant for a total of 36 trials. One participant was removed from analysis due to a missing trial. Movement times generally decreased across practice Days 1 and 2 (*Figure 1*). A repeated measures ANOVA indicated significant main effects of day, F (1,19) = 9.318, $p < .05$, and trial, F (11,19) = 24.739, $p < .05$ (Figure 1). The Day x Group interaction was also significant, F (1,19) = 10.913, $p < .05$). Post-hoc tests indicated the internal group performed the movement significantly faster than the external group on Day 1 (t = 2.369, $p < .05$), but not Day 2.

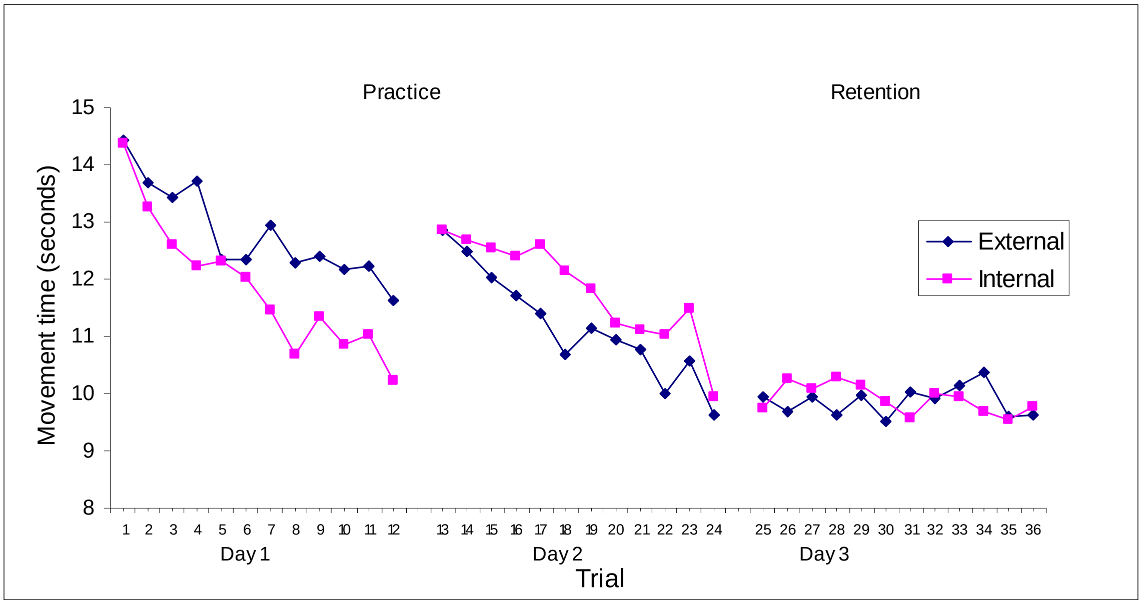

Figure 1. Movement times of both groups during practice and retention.

<u>Distance Reached</u>

Distance reached relative to each participant's baseline measurement on the first and last trial of each practice day showed a decreasing trend on Days 1 and 2 for the external group (*Figure 2*). The internal focus group demonstrated inconsistent patterns of distance reached from Day 1 to Day 2. No significant main effect of day, F (1, 20) = 1.352, p = .259, and no significant main effect of trial, F (1, 20) = 1.855, p = .188, were present. Neither group demonstrated greater performance on the reach over the other, F (1,20) < 1. There were no significant interactions of day x group, F (1,20) < 1, trial x group, F (1,20) = 2.338, p = .142, day x trial, F (1,20) = 1.297, p = .268, or day x trial x group, F (1,20) < 1.

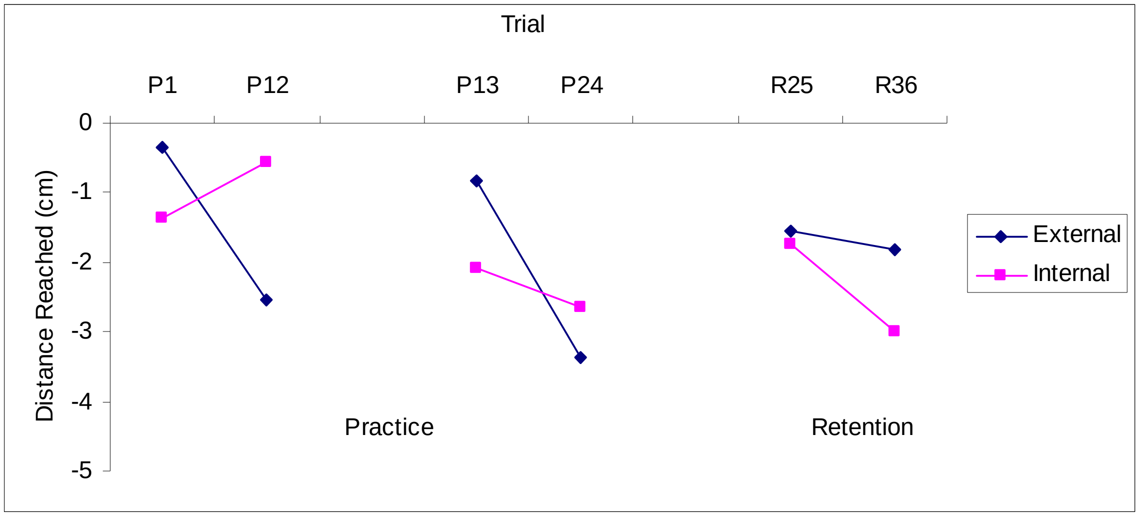

Figure 2. Distance reached relative to the participant's baseline reach measurement (0).

Form Scores

On Day 1, form scores decreased in both groups from the first practice trial to the last practice trial (*Figure 3)*. On Day 2, form scores remained more consistent. The main effect of day was significant, F (1, 20) = 7.530, p < .05. Both groups demonstrated improved performance on Day 2. However, the main effect of trial was not significant, F (1, 20) = 3.193, p = .089. There was no significant main effect of group, F (1, 20) < 1, indicating no difference in form between groups. No significant interactions were present for day x group, F (1, 20) < 1, trial x group, F (1, 20) < 1, day x trial, F (1, 20) = 2.293, p = .146, or day x trial x group, F (1, 20) < 1.

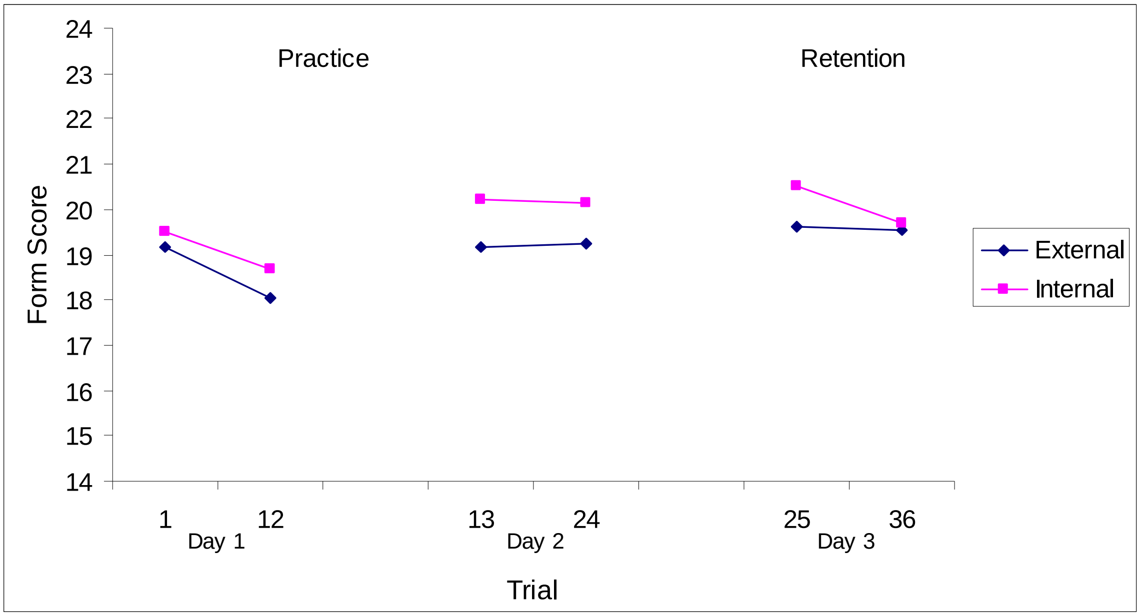

Figure 3. Form scores for both groups on the first and last trial of each practice day and retention test.

Retention

Movement Time

Movement time was consistent across groups and trials on Day 3 (*Figure 1*). Mauchly's test indicated a violation of sphericity, $p < .05$, so the Huynh-Feldt correction was used. One participant was removed from analysis due to a missing trial. There was no significant main effect of trial, F (11, 209) < 1, and no significant main effect of group, F (1, 19) < 1. There was no significant Trial x Group interaction, F (11, 209) =1.067, p = .388.

Distance Reached

Both groups demonstrated a decrease in distance reached from the first trial on Day 3 to the last trial (*Figure 2)*. The main effect of trial was not significant, F (1, 20) < 1, and there was no significant main effect of group, F (1, 20) < 1. Additionally, there was no Trial x Group interaction, F (1, 20) < 1.

Form Scores

On Day 3, form scores showed a decreasing trend for the internal group, and minimal variability for the external group (*Figure 3)*. For retention, there was no significant main effect of group, F (1, 20) < 1, and no significant main effect of trial, F (1, 20) < 1. Additionally there was no significant Trial x Group interaction, F (1, 20) < 1.

CHAPTER 5

DISCUSSION

Discussion of Results

The main purpose of this experiment was to determine whether inducing an internal or external focus of attention while learning a Pilates roll-up had an effect on movement technique acquisition. The assessed variables of movement time, distance reached while in flexion, and movement form scoring produced limited findings about the effect of attentional focus manipulation on novice learning of a Pilates roll-up. These results are in contrast to findings of previous studies in which an external focus of attention was found to have positive effects on performance of motor skills after practice (Wulf, 2007a). Limiting factors of practice time and the chosen skill itself may have contributed to the present findings, as well as differences in experimental design between the present study and previous research.

Movement Time

Movement time decreased across both groups as practice time increased. Participants performed with greater movement time consistency on the retention day than during the practice phase. The difference in movement time between groups observed on the first day was not present on the second day or in retention. Therefore the initial group difference is not an indication of a true effect of focus on movement time. In certain skills, performing a movement faster may indicate the skill is being executed more efficiently, however this is not necessarily true of the roll-up. The goal of the movement was to achieve the proper modeled form. There was no indication that differences in movement time related to fluctuation in form scores, so a relationship between the two variables cannot be made.

Distance Reached

Distance reached while in the flexion phase of the movement was evaluated as a measure of successful form. No group differences or effect of time spent practicing suggest that altering focus of attention influenced the participants' tendency to reach to or beyond their baseline reference point of pre-performance maximum reach (*Figure 2*). In previous literature, participants have been able to perform more effectively on skills such as biceps curls and basketball free throws under external focus (Vance et al., 2004; Zachry et al., 2005). This skill enhancement was linked to automaticity achievement, as demonstrated, for example, by reduced EMG activity, or constraint on the motor system. In the present experiment, it was not expected that participants would reach past their baseline measurement due to focus, but rather that the internal group would have been constrained from reaching as far as the external group. In both practice and retention, both groups reached comparable distances relative to baseline across all trials. This indicates that neither focus group necessarily constrained the action and therefore cannot be attributed to performance inhibition.

Form Scores

Components of movement form were assessed and scored by raters trained in the skill components and scoring procedure. Both conditions showed similar patterns in movement form scores, but no significant effect on skill learning was found as a function of attentional focus. The main finding of the study was expected to produce evidence of skill enhancement through external focus as expressed by movement form scores.

Limitations in the chosen skill and study design provide possible explanation for the observed results.

The Pilates roll-up was the chosen skill because it is a task which requires adherence to technique in order to complete the movement successfully. Task difficulty was not an issue because all participants were able to complete the roll-up on every trial. A major difference that arises between the roll-up task and tasks observed in previous experiments is the lack of object manipulation. In laboratory tasks such as balancing on the stabilometer or ski-simulator, or in sport examples such as golf or basketball, the external focus instruction guided the performer's attention to the object the movement was to have an effect on (Wulf et al., 1997, 1998, 1999; Zachary et al., 2005). In the present study, external focus instructions referred to images or locations outside the body in attempt to remove focus from the movement of the body segments themselves. When the goal of the movement is to make the body achieve a certain form, external focus instructions may not be applicable in the way they are for tasks with object manipulation. In the post-participation questionnaire administered to participants, both the internal and external groups reported a strong focus on the specific placement of their body and less attention paid to images unrelated to their bodies. This occurred despite the participants also reporting that the instructions given to them highly influenced their learning of the task. Thus, an added challenge emerges in assigning external focus instructions for a skill in which the movement effect is body-related, not object-related.

A second divergent factor from the previous literature was the lack of observable learning of the roll-up during retention testing. The form scores of both groups on Day 2 was significantly better than the form scores on Day 1, but the learning effect did not carry over to retention testing (*Figure 3)*. In studies that have found an external focus advantage, the effect occurs in conjunction with demonstration of skill learning or expertise at the task (Perkins-Ceccato et al., 2003; Wulf et al., 1998). In other words, a certain amount of practice and learning of the skill may be necessary before an external focus advantage can take place in complex movement tasks. The practice time allowed by the current experiment does not indicate the type of effect attentional focus may have had under prolonged practice periods.

It has also been found that complex skill performance benefits from a combination of awareness and nonawareness strategies as proposed in the Five-Step Approach (Singer et al. 1993). In this strategy there is an added element of allowing the performer both time to mentally prepare for the act before execution, and time to evaluate post-performance outcome. With the roll-up task, a strategy such as the Five-Step Approach would be possible as there is no time constraint. The nature of the task also requires a specific movement routine to be planned and executed.

Finally, a previously validated rating scale was not available for the task at hand. Previous research involving rating scales have used varied approaches in methodology (Uehara et al., 2008; Weeks et al., 2005; Zentgraf & Munzert, 2009; Wulf et al., 2002). The present experiment required development of a new rating scale and interpretation of results based on limited availability of raters. There is a trend in the literature of inconclusive findings with performance rating systems that reveals a weakness in the implementation of such studies (Uehara et al.; Weeks et al., Wulf et al.). For future research to continue in the subjective evaluation of movement form, a reliable scale needs to be developed.

Conclusions and Recommendations for Further Research

In conclusion, guided instruction for the Pilates roll-up with different focus of attention manipulations did not result in group differences for the learning and performance of the task. Further research is needed to establish a relationship between focus of attention and complex skill learning in which movement form is emphasized in execution. Factors such as level of the performer, adequate practice time, inclusion of additional focus strategies, and use of validated rating scales should be considered.

APPENDIX 1

STATISTICS

Movement Time: Practice Phase

Within-Subjects Factors

Measure:MEASURE_1

Day	Trial	Dependent Variable
1	1	P1
	2	P2
	3	P3
	4	P4
	5	P5
	6	P6
	7	P7
	8	P8
	9	P9
	10	P10
	11	P11
	12	P12
2	1	P13
	2	P14
	3	P15
	4	P16
	5	P17
	6	P18
	7	P19
	8	P20
	9	P21
	10	P22
	11	P23
	12	P24

Between-Subjects Factors

		Value Label	N
Group	1.00	External	11
	2.00	Internal	10

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Day	Sphericity Assumed	75.214	1	75.214	9.318	**.007**	.329	9.318	.825
Day * Group	Sphericity Assumed	88.087	1	88.087	10.913	**.004**	.365	10.913	.880
Error(Day)	Sphericity Assumed	153.359	19	8.072					
Trial	Sphericity Assumed	382.877	11	34.807	24.739	**.000**	.566	272.129	1.000
Trial * Group	Sphericity Assumed	13.842	11	1.258	.894	.547	.045	9.838	.492
Error(Trial)	Sphericity Assumed	294.057	209	1.407					
Day * Trial	Sphericity Assumed	13.167	11	1.197	1.077	.381	.054	11.848	.588
Day * Trial * Group	Sphericity Assumed	15.968	11	1.452	1.306	.223	.064	14.368	.693
Error(Day*Trial)	Sphericity Assumed	232.268	209	1.111					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	69620.475	1	69620.475	376.849	.000	.952	376.849	1.000
Group	25.047	1	25.047	.136	.717	.007	.136	.064
Error	3510.132	19	184.744					

a. Computed using alpha = .05

Simple Main Effects: Day

Estimates

Measure:MEASURE_1

Day	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	12.153	.626	10.842	13.464
2	11.380	.612	10.099	12.661

Day * Group Interaction

4. Group * Day

Measure:MEASURE_1

Group	Day	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
External	1	12.795	.864	10.986	14.604
	2	11.184	.845	9.416	12.953
Internal	1	11.511	.906	9.614	13.409
	2	11.575	.886	9.721	13.430

Post Hoc Analysis

Group Statistics

	Group	N	Mean	Std. Deviation	Std. Error Mean
P1	External	132	12.7949	3.54555	.30860
	Internal	132	11.8706	2.74317	.23876

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
P1	Equal variances assumed	9.488	**.002**	2.369	262	.019	.92437	.39018	.15608	1.69266
	Equal variances not assumed			2.369	246.461	**.019**	.92437	.39018	.15586	1.69289

Simple Main Effects: Trial

Estimates

Measure:MEASURE_1

Trial	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	13.471	.599	12.217	14.724
2	12.863	.673	11.454	14.272
3	12.462	.698	11.002	13.922
4	12.412	.650	11.052	13.771
5	12.006	.571	10.811	13.201
6	11.598	.646	10.246	12.951
7	11.702	.654	10.334	13.070
8	11.155	.612	9.874	12.436
9	11.236	.614	9.951	12.521
10	10.858	.603	9.595	12.121
11	11.143	.664	9.754	12.532
12	10.293	.575	9.090	11.495

Movement Time: Retention Phase

Within-Subjects Factors

Measure:MEASURE_1

Trial	Dependent Variable
1	R1
2	R2
3	R3
4	R4
5	R5
6	R6
7	R7
8	R8
9	R9
10	R10
11	R11
12	R12

Between-Subjects Factors

		Value Label	N
Group	1.00	External	11
	2.00	Internal	10

Mauchly's Test of Sphericity[b]

Measure:MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Trial	.000	138.399	65	**.000**	.437	.635	.091

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Mauchly's Test of Sphericity[b]

Measure:MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Trial	.000	138.399	65	**.000**	.437	.635	.091

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept + Group

Within Subjects Design: Trial

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Trial	Huynh-Feldt	5.811	6.980	.832	.774	.610	.039	5.399	.323
Trial * Group	Huynh-Feldt	8.014	6.980	1.148	1.067	.388	.053	7.447	.446
Trial (Error)	Huynh-Feldt	142.728	132.619	1.076					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	24105.298	1	24105.298	255.715	.000	.931	255.715	1.000
Group	1.410	1	1.410	.015	.904	.001	.015	.052
Error	1791.060	19	94.266					

Tests of Between-Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	24105.298	1	24105.298	255.715	.000	.931	255.715	1.000
Group	1.410	1	1.410	.015	.904	.001	.015	.052
Error	1791.060	19	94.266					

a. Computed using alpha = .05

Distance Reached: Practice Phase

Within-Subjects Factors

Measure:MEASURE_1

Day	Trial	Dependent Variable
1	1	P1
	2	P12
2	1	P13
	2	P24

Between-Subjects Factors

		Value Label	N
Group	1.00	External	11
	2.00	Internal	11

Descriptive Statistics

	Group	Mean	Std. Deviation	N
P1	External	-.0036	.02335	11
	Internal	-.0136	.04456	11
	Total	-.0086	.03509	22
P12	External	-.0255	.05502	11
	Internal	-.0055	.03205	11
	Total	-.0155	.04512	22
P13	External	-.0082	.04729	11
	Internal	-.0209	.05049	11
	Total	-.0145	.04818	22
P24	External	-.0336	.07433	11
	Internal	-.0264	.04130	11
	Total	-.0300	.05880	22

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Day	Sphericity Assumed	.002	1	.002	1.352	.259	.063	1.352	.198
Day * Group	Sphericity Assumed	.000	1	.000	.193	.665	.010	.193	.070
Error(Day)	Sphericity Assumed	.034	20	.002					
Trial	Sphericity Assumed	.003	1	.003	1.855	.188	.085	1.855	.254
Trial * Group	Sphericity Assumed	.003	1	.003	2.338	.142	.105	2.338	.307
Error(Trial)	Sphericity Assumed	.029	20	.001					
Day * Trial	Sphericity Assumed	.000	1	.000	1.297	.268	.061	1.297	.192
Day * Trial * Group	Sphericity Assumed	.000	1	.000	.435	.517	.021	.435	.096
Error(Day*Trial)	Sphericity Assumed	.006	20	.000					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	.026	1	.026	4.458	.048	.182	4.458	.520
Group	2.841E-5	1	2.841E-5	.005	.945	.000	.005	.051
Error	.116	20	.006					

a. Computed using alpha = .05

Distance Reached: Retention Phase

Within-Subjects Factors

Measure:MEASURE_1

Trial	Dependent Variable
1	R25
2	R36

Between-Subjects Factors

		Value Label	N
Group	1.00	External	11
	2.00	Internal	11

Descriptive Statistics

	Group	Mean	Std. Deviation	N
R25	External	-.0155	.04865	11
	Internal	-.0173	.05461	11
	Total	-.0164	.05048	22
R36	External	-.0182	.05344	11
	Internal	-.0300	.06826	11
	Total	-.0241	.06013	22

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Trial	Sphericity Assumed	.001	1	.001	.937	.345	.045	.937	.152
Trial * Group	Sphericity Assumed	.000	1	.000	.392	.538	.019	.392	.092
Error(Trial)	Sphericity Assumed	.014	20	.001					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	.018	1	.018	3.141	.092	.136	3.141	.393
Group	.001	1	.001	.089	.768	.004	.089	.059
Error	.115	20	.006					

a. Computed using alpha = .05

Intraclass Correlation Coefficient

Case Processing Summary

		N	%
Cases	Valid	132	100.0
	Excluded[a]	0	.0
	Total	132	100.0

a. Listwise deletion based on all variables in the procedure.

Intraclass Correlation Coefficient

	Intraclass Correlation[a]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.752[b]	.666	.818	7.248	131	131	.000
Average Measures	.858	.799	.900	7.248	131	131	.000

Two-way random effects model where both people effects and measures effects are random.

a. Type A intraclass correlation coefficients using an absolute agreement definition.

b. The estimator is the same, whether the interaction effect is present or not.

Form Scores: Practice Phase

Within-Subjects Factors

Measure:MEASURE_1

Day	Trial	Dependent Variable
1	1	P1
	2	P12
2	1	P13
	2	P24

Between-Subjects Factors

		Value Label	N
Group	1.00	External	11
	2.00	Internal	11

Descriptive Statistics

	Group	Mean	Std. Deviation	N
P1	External	19.1818	5.17819	11
	Internal	19.5000	3.14643	11
	Total	19.3409	4.18440	22
P12	External	18.0455	4.44103	11
	Internal	18.6818	4.29693	11
	Total	18.3636	4.27669	22
P13	External	19.1818	4.33747	11
	Internal	20.2273	3.25087	11
	Total	19.7045	3.77857	22
P24	External	19.2273	5.28850	11
	Internal	20.1364	3.20227	11
	Total	19.6818	4.29159	22

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Day	Sphericity Assumed	15.557	1	15.557	7.530	**.013**	.274	7.530	.742
Day * Group	Sphericity Assumed	1.375	1	1.375	.666	.424	.032	.666	.122
Error(Day)	Sphericity Assumed	41.318	20	2.066					
Trial	Sphericity Assumed	5.500	1	5.500	3.193	.089	.138	3.193	.398
Trial * Group	Sphericity Assumed	.045	1	.045	.026	.873	.001	.026	.053
Error(Trial)	Sphericity Assumed	34.455	20	1.723					
Day * Trial	Sphericity Assumed	5.011	1	5.011	2.293	.146	.103	2.293	.303
Day * Trial * Group	Sphericity Assumed	.284	1	.284	.130	.722	.006	.130	.064
Error(Day*Trial)	Sphericity Assumed	43.705	20	2.185					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	32686.545	1	32686.545	500.725	.000	.962	500.725	1.000
Group	11.636	1	11.636	.178	.677	.009	.178	.069
Error	1305.568	20	65.278					

a. Computed using alpha = .05

Simple Main Effects: Day

Estimates

Measure:MEASURE_1

Day	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	18.852	.886	17.004	20.700
2	19.693	.864	17.892	21.495

Form Scores: Retention Phase

Within-Subjects Factors

Measure:MEASURE_1

Trial	Dependent Variable
1	R25
2	R36

Between-Subjects Factors

		Value Label	N
Group	1.00	External	11
	2.00	Internal	11

Descriptive Statistics

	Group	Mean	Std. Deviation	N
R25	External	19.6364	4.89434	11
	Internal	20.5000	3.44238	11
	Total	20.0682	4.15273	22
R36	External	19.5455	4.11980	11
	Internal	19.6818	4.45686	11
	Total	19.6136	4.18879	22

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Trial	Sphericity Assumed	2.273	1	2.273	.797	.383	.038	.797	.136
Trial * Group	Sphericity Assumed	1.455	1	1.455	.510	.483	.025	.510	.105
Error(Trial)	Sphericity Assumed	57.023	20	2.851					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure:MEASURE_1

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	17321.114	1	17321.114	517.522	.000	.963	517.522	1.000
Group	2.750	1	2.750	.082	.777	.004	.082	.059
Error	669.386	20	33.469					

a. Computed using alpha = .05

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