2005

The Effects of Physiological Arousal on Measures of Upper Extremity Position Sense in Healthy Young Adults

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THE EFFECTS OF PHYSIOLOGICAL AROUSAL
ON MEASURES OF UPPER EXTREMITY POSITION SENSE
IN HEALTHY YOUNG ADULTS

By
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A thesis submitted to the faculty of The University of Mississippi in partial fulfillment of the requirements for the Sally McDonnell Barksdale Honors College

Oxford
May 2005

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ACKNOWLEDGEMENTS

The four years I have spent at the University of Mississippi have been much more than I ever imagined. I have been challenged throughout my college career, both academically and socially. This thesis has summed up my years as an Ole Miss student, and I leave with a great sense of accomplishment.

I was not planning on completing my thesis, but with the help of some very important people, the impossible was made a reality. First, I would like to thank Dr. Chris Kovacs for his support, motivation, and guidance. The day I approached Dr. Kovacs asking for someone to perform a research study under he was eager to help. He never lost faith in me and always motivated me to do what he knew I was capable of doing. He guided me throughout everything, trusted me with his research study, and rearranged his deadlines to make sure I could meet mine. He was the most unselfish mentor, and I could not have fulfilled my thesis requirements without him.

I am also grateful for the support and suggestions from Dr. Scott Owens and Dr. Linda Chitwood. These members from my thesis committee encouraged me and made me feel like I had successfully accomplished my largest feat since entering the university. The suggestions, though they may seem small to some, made my thesis go from finished to complete with all the finishing touches. I cannot thank them enough for the time they each spent to better my thesis.

I can't forget all the others who influenced me along the way and pushed me to continue when I felt I could do no more. All my friends and especially my family who thought I was MIA for a while, I couldn't have tackled my thesis without the motivation I drew from the love and support of such special people. Although this thesis is my fulfillment to the Sally McDonnell Barksdale Honors College, it is the accomplishment of all my friends and family who supported me as well. I could not have done this without you!

ABSTRACT

MELISSA ANGELIQUE PARKER: The Effects of Physiological Arousal on Measures of Upper Extremity Position Sense in Healthy Young Adults
(Under the direction of Christopher Kovacs)

The purpose of this investigation was to examine the effects of physiological arousal on the ability to perceive upper extremity position in healthy young adults. Heart rate measurements and blood pressure measurements were taken at pre-established intervals during data collection. Pre-stressor and post-stressor upper extremity trials were also recorded. Twenty participants, 12 females and 8 males, with a mean age of 22.3 (20-33) years comprised the experimental sample. Participants in the experimental sample underwent a combination of the Stroop color-word task and simple math problems to produce a state of arousal and were pre and post tested for upper extremity position sense.

The absolute error score averages were calculated for each subject. The pre-test absolute error scores and post-test absolute error scores were compared. A paired t-test revealed a significant difference ($p < .05$) between the pre-test trials and the post-test trials.

The purpose of this investigation was to examine how arousal effects position sense in healthy young adults. The results suggest under a state of arousal proprioceptive measures decrease. The decrease in perception ability is attributed to changes within the central nervous system, specifically the sympathetic nervous system.

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INTRODUCTION

Walking across campus between classes, working out in the gym and writing notes during a business meeting all require a shared ability. Each task performed throughout the day, whether it is gait, balance, coordination, or functional depends upon the ability to perform motor functions accurately. In performing these motor functions no conscious command tells our arm or leg where it is or where it should be going. Nonetheless, locating a pen on the desk or lifting our leg high enough to step over a curb or onto the next stair is not difficult. Position is judged in relation to the environment. How high our knee should be lifted or our arm should be extended is sensed. Daily processes are performed precisely without contemplating body orientation during the performance of such tasks all through proprioception.

Proprioception is our body's ability to judge the position of our extremities in relation to our environment, (Euzet, 1995; Laskowski, 1997; Park, 1999; Helmuth, 2000; Lonn, 2000; Worringham, 2000; Matre, 2003; Carello, 2004). Knowledge of body position relies on several senses, both visual and non-visual, (Euzet, 1995). Collectively visual cues, touch sensations, and proprioceptive measures are used to determine body position, (Helmuth, 2000). Animals and people alike rely on these senses to indicate limb position.

Despite the unifying need for proprioception, several distinct definitions are used to describe proprioception. All descriptions differ slightly but illustrate the same concept. Laskowski, Newcomer-Aney, and Smith (1997), for example, depict proprioception as a somatic sense, a function of the nervous system in which information from the body is collected without the use of the senses such as sight, hearing, taste, sound, or vestibular equilibrium. The ability to sense the location of the upper extremity in relation to another part of the body without visual stimulation is kinesthesia, (Euzet, 1995).

Stressful situations can alter the body's autonomic nervous system, the immune system, and areas of the brain processing somatosensory information, (Kemeny, 2003). Unfortunately, today's society places loads of stress on young adults. Lectures and tests, searching and interviewing for a job, adjusting to a job, meeting deadlines, getting married, purchasing a first home, starting a family and other responsibilities of "growing up" all place psychological strains on today's young adults. Many young adults, in turn, have learned to cope with stress, and the stress young adults experience does not evidence itself while fulfilling daily duties.

However, stress could produce effects of which young adults are unaware. Stress increases arousal and could alter our daily movements unwillingly and seemingly undetectably. First, an understanding of the term stress must be sustained. Although stress is rarely and vaguely described in literature, stress can be characterized as any stimulus, response to a stimulus, or a physiological consequence specific to a stimulus response, (Kemeny, 2003). The types of stimuli characteristic of stress can be considered stressors, either physical, effecting the body, or psychological, effecting psychological health. In response to these stressors, physical responses can be seen within both the nervous and cardiovascular systems, known as physiological arousal. For this study stress will be characterized as a factor producing physiological arousal, a resulting condition. Changes in the nervous system affect accurate performance of motor skills.

Ballistic movements or unexpected environmental changes, such as a pedestrian in the crosswalk, a rise or crack in the sidewalk, or a slippery floor, can also play a role as stressors and also increase physiological arousal. Under a state of increased physiological arousal, attention is directed toward one stimulus creating a deficit in the ability to multi-task. Talking on a cell phone while driving, for instance, reduces the driver's ability to properly attend and steer around an obstacle, react to a stop light, or control driving speed reasonably well. These types of alterations can increase the incidence of car accidents or in other scenarios possibly promote falls during normal gait.

The issue of physiological arousal and how it affects the ability to accurately sense body position in space has not been investigated directly. Studies have looked at how arousal affects other areas of life and performance of specific skills but not proprioception specifically. The loss of accurate proprioceptive sense could decrease coordination and balance, which could increase the incidence of falls, especially in elderly individuals. With a lifestyle encouraging stress and physiological arousal, and the vast baby boomer population breaching old age, the consequences of induced stress on proprioception should be investigated further.

Statement of the Problem

The primary purpose of this investigation is to determine if a state of increased physiological arousal affects the ability of an individual to sense the position of an upper extremity in space. Specifically, the following hypothesis is explored:

Hypothesis

An increased state of physiological arousal will produce an increase in position sense absolute error between the pre-test upper extremity trials and the post-test upper extremity trials.

REVIEW OF RELATED LITERATURE

The following is a discussion of research involving proprioceptive feedback, physiological arousal, the role of proprioception in motor performance, and proprioceptive training. Previous studies evaluating proprioception and how it affects various aspects of motor function will also be discussed. In addition, arousal and the affects of arousal on both the physical and physiological bearings will be reviewed.

Proprioception

In 1906, Sherrington viewed proprioception in his study as feedback from the periphery to the nervous system, (Dover, 2003). Since Sherrington, others have defined proprioception as a sense of joint awareness or, more ambiguously, as neuromuscular control, (Laskowski, 1997). Proprioception is a complex concept including position sense, velocity of movement, detection of movement, and force sensations, (Lonn, 2000; Dover, 2003). Proprioception was originally synonymous with 'muscular sense', (Lonn, 2000). Despite the numerous definitions concerning proprioception, position sense, actual awareness of the limb, is presently acknowledged as the most accepted interpretation.

The ability to detect position has been evaluated in previous studies. Some studies examine how proprioception is affected by overuse, while others evaluate proprioception following an injury or surgery. Dover, Kaminski, Meister, Powers, and Horodyski (2003) researched the effects of overuse on position sense abilities. This study examined the proprioceptive ability of the dominant arm, throwing arm, with the non-dominant shoulder to determine if the dominant arm suffers from position sense deficits due to repetitive use.

The subjects were brought into the lab and asked to wear an inclinometer on the elbow. The degree of internal and external rotation was measured on each subject. Based on the degree of rotation, both internal and external, capable of being performed by each subject, target angles were adjusted, (Dover, 2003). The target angles were then asked to be reproduced after the subject's arm was moved to the target angle, held for three seconds, and then returned back to neutral; the subject was blindfolded. Four target angles were tested on both the dominant and non-dominant arm. Both the groups, athletes and control, evidenced a higher degree of external rotation in the dominant arm than the non-dominant arm.

Following completion of the study, it was concluded the athletes demonstrate a greater external rotation error score than the control group when reproducing a target angle, (Dover, 2003). The findings of the study suggest overhand sports, such as softball examined in this study, decrease external rotation position sense. Although, whether decreased position sense is present in only the dominant shoulder or both shoulders of the athlete as compared with the control is unclear.

The decrease in proprioceptive ability in the shoulder of an athlete could mean one of two things, however. First, the decrease in proprioceptive ability may increase the incidence of injury in an athlete. With decreased proprioception the information received from proprioceptors may not be processed in response to forceful movements leading to tearing or straining a muscle, insensitive joint receptors to extreme angular motions and cause spraining or tearing of ligaments, (Dover, 2003). Second, an injury due to the nature of the sport may cause a decrease in position sense, such as a strained hamstring may not produce accurate adjustments in force due to desensitized proprioceptors and appropriate information may not be delivered to the somatosensory cortex. The relationship between proprioception and injury has not been established.

Swanik, Lephart, and Rubash (2004) were interested in how proprioception was affected by total knee arthroplasty of the posterior cruciate ligament. The posterior cruciate ligament contains several mechanoreceptors, which detect both position sense and kinesthesia. Patients with severe degenerative joint disease often require a total knee arthroplasty to reduce pain and inflammation and restore proper function. However, preservation of the posterior cruciate ligament is believed to improve joint sensation.

The proprioceptive measurements were evaluated prior to surgery and six months following one of the two procedures, either the cruciate-retaining or the posterior stabilized prosthesis, (Swanik, 2004). During evaluation the subjects were asked to passively reproduce the same lower leg position three consecutive times. Following evaluation of the difference between the presented angle and the reproduced angle, it was inferred following total knee arthroplasty the ability to detect and reproduce the knee angle increased. The group receiving the posterior stabilized prosthesis improved proprioception significantly in extension of the knee.

The improvement in proprioceptive ability can be attributed to the demise of the pain, laxity, tight joints, and also the maintenance of joint receptors, (Swanik, 2004). Restoring the joint space and soft tissue of the knee leads to modifications within the receptors. The mechanoreceptors in both the capsuloligamentous and musculotendinous structures respond more appropriately and enhance the ability to perceive position. Degenerative knee disorders haunt many elderly. Often total knee replacement surgeries are required as treatment for "bad knees". The study by Swanik provides perhaps a better option when performing knee surgeries to help maintain proprioceptive function, especially in elderly who exhibit gait difficulties prior to surgery.

Importance of Proprioception

The information brought into the muscle tissue via the proprioceptive receptors is necessary to detect kinesthesia, joint motion, and position sense, and orientation of the body in space, (Kablan, 2004). The ability to efficiently obtain information through the proprioceptive receptors prevents inaccuracy in movement, which could lead to overshooting or undershooting an obstacle in gait, over steering while driving, or over-rotating while throwing a ball, all of which could cause an accident or injury.

Proprioception is important to control muscular activities, which require sequential firing within the muscle, (Kablan, 2004). Without proprioceptive feedback, the location and control of a limb in motion will be harder to perceive and organize, (Park, 1999). Coordination, characterized by smooth, rhythmic muscle activity, depends upon directional guidance between visual and proprioceptive sensory motor-systems, (Redding, 1992).

Balance also depends upon joint motion and position sense, (Swanik, 2004). A loss in joint sensations has been recognized as a factor contributing to balance deficits in elderly. Patients suffering from osteoarthritis also demonstrate a higher incidence of falls than age-matched controls. Thus, a loss in balance due to decreased joint motion and position sense poses a serious health risk as they have been predicted to increase the number of falls among the elderly population.

Somatosensory System

Being aware of the body's position in relation to the environment can prevent undesirable collisions or mishaps. More appropriate approximations regarding body position can increase the ease of performing specific tasks successfully. Determining where the body is in space relies largely upon sensory information such as proprioception. For example, when running the joint receptors allow the body to predict where the feet will be at a given time and adjustments are continuously made as needed, (Luttgens, 1997). Proprioceptors are also responsible for making accommodations when a cup perceived to be heavy is actually much lighter; the proprioceptors therefore reduce the amount of force produced instantaneously.

Extremity movement is accompanied by kinesthesia, which provides afferent information from the body to the motor areas in the central brain, (Swartz, 1978). The information is processed comparing the position of the limb with the intended position of the limb, which is corrected with a compensatory muscle movement, (Laskowski, 1997).

Information sent to the central nervous system distinguishes limb position as one of two types, either static or dynamic. Static proprioception provides information about where a limb is in relation to another body part while dynamic proprioception provides information about how fast a limb is moving and the direction of movement.

Before reaching the brain, proprioceptive information originates in the mechanoreceptors, proprioceptors, (Laskowski, 1997). Proprioceptors are receptors in the muscle, such as muscle spindles, golgi tendon organs, and joint receptors, (Luttgens, 1997; Latash 1998; Park, 1999; Riley, 2003; Carello, 2004). The proprioceptors provide information about body position. Muscle spindles, narrow structures lying parallel to the skeletal muscle fibers, appear to provide most of the information about changes in position, (Park, 1999). Muscle spindles are intrafusal muscle fibers with ends connected to the extrafusal fibers. As the extrafusal fiber is stretched, the intrafusal fiber stretches as well. The information about the stretch of the muscle is perceived.

Golgi tendon organs provide information about the force production within a muscle. Golgi tendon organs lie within the junction between the tendon and the muscle. As deformation in the muscle-tendon complex occurs the golgi tendon organ senses the distortion and stimulation of the receptor results. Golgi tendon organs are not sensitive to the rate of change within the muscle-tendon complex but instead sense the magnitude of force. Golgi tendon organs generally do not respond to passive movement unless the movement produces a considerable amount of force.

The joint receptors, or articular receptors, are located within the joint. These receptors are angle transducers and respond to the angle of the joint during dynamic movement. These receptors are sensitive within a narrow range of motion and some only respond at joint extremes. The different types of proprioceptors, muscle spindles, golgi tendon organs, and joint receptors, work together to provide coordination of movement and interpretation of the environment.

The stimulus beginning in the proprioceptors is transferred from the proprioceptor along the afferent axon of the ganglionic neuron into the dorsal column root in the spinal cord. The signal moves into the low-threshold dorsal column pathway and along afferent fibers within the ipsilateral dorsal column and synapse in medulla with the dorsal column nuclei. The signal is then transferred across the midline of the body to the contralateral side of the brain to the ventral posterior nucleus of the thalamus. The thalamus transmits the sensory information to the sensory cortical areas in the parietal cortex, (Latash, 1998).

The somatosensory cortex is located toward the front of the parietal lobes. In the somatosensory cortex exists a small map of the human body, the sensory homunculus. This is the somatosensory projection area. The map of the body represented in the somatosensory projection area is both inverted and improportionally represented. The information is processed in the parietal cortex and mapped on the somatosensory projection to consciously perceive position, (Sherwood, 2001). Given the importance of, and dependence upon, proprioceptive information for coordination, a large portion of the brain is devoted to deciphering proprioceptive sensations and ordering body movements, (Helmuth, 2000).

Motor System

Prior to any movement, the muscular activation within the limb, position of the limb, and torque on the limb assist in perceiving original limb placement, (Park, 1999).

As movement occurs information is continuously sent from the muscle spindles of the antagonist muscle regarding movement velocity and joint angles. As the opposing muscle is moved or activated, information about the stretched muscle is sent through the afferent pathway into the spinal cord via the dorsal root ganglion to the brain and location of the limb is perceived.

The information producing motor control is processed via the efferent division of the peripheral nervous system. The efferent nervous system consists of the somatic nervous system, controlling skeletal muscle movements, and the autonomic nervous system, which controls smooth muscle, such as the blood vessels, cardiac muscle within the heart, and the activity of glands, (Sherwood, 2001). The information is sent to the muscles from the central nervous system via either the pyramidal tract or the extrapyramidal tract. The pyramidal tract is named for the passage it makes through the medullar pyramids. The pyramidal tract is the fastest conductor of information and provides a direct track from the cortex to the muscles. Minimal synapses are present along some of the longest axons in the body allowing information to travel more rapidly. Most of the long axons of the pyramidal tract cross over the pyramidal decussation to the contralateral side of the body where they synapse onto the motor interneurons. Those not crossing at the pyramidal decussation continue to further down on the spinal cord and cross the midline of the body where they synapse with the motoneurons. The pyramidal tract is associated with control of precise movements.

Conversely, the extrapyramidal tract does not pass through the medullar pyramids. This tract passes information from the cerebral cortex and other cortical areas along axons with multiple synapses to motor areas of the brain. Gross motor movements such as postural control are associated with extrapyramidal control. It has been suggested an efferent copy is formed to represent a motor command and aids in deciphering information received from proprioceptors, (Latash, 1998).

Arousal and Motor Performance

Before an understanding of how arousal affects motor performance, arousal and the indicators of arousal must first be understood. Stress affects the autonomic nervous system and increases the use of defense mechanisms; the increase in defense mechanisms can be related to a heightened sense of physiological arousal, (Cramer, 2003).

The autonomic responses to stress brought on by behavioral or cognitive processes are associated with an increase in both diastolic and systolic blood pressure, (Cramer, 2003). The increase in blood pressure results due to alterations within the parasympathetic and sympathetic systems, which modulate the heart. Any type of ego defense mechanism should require cognitive activity. Cognitive activity is related to an elevation in diastolic blood pressure. Since physiological arousal can be evidenced in blood pressure, during research collection it is feasible to use blood pressure measures as an indicator of a state of arousal.

Arousal can arise from several different situations and produce several different effects on the body. Test anxiety, for example, is one type of physiological arousal, which arises from evaluative stress, (Calvo, 1987). Calvo and Alamo (1987) investigated how test anxiety, a type of physiological arousal, affects motor performance. The hypothesis suggested test anxiety would effect fine motor control but not gross motor control. During the study, the relationship between anxiety and motor performance is attributed to the attention needs and neuromuscular requirements for a task.

In producing a stimulus response, the more stimuli present the more widespread the response, (Calvo, 1987). In other words, situations presenting several stimuli can create an inaccurate response due to the lack of attention allotted for evaluation of each separate stimulus and each stimulus response. Similarly, the more complex the response, the more neuromuscular control needed to produce an accurate response. When several stimuli are present, each requiring lots of attention to produce a response involving several muscle bodies or proprioceptors, not all the stimuli will receive an accurate response and the large need for neuromuscular response can cause a deficit in production of an appropriate neuromuscular response.

The appropriate performance of a motor task, however, requires correct functioning of the muscle effectors, muscle spindles, and the proprioceptive receptors, (Calvo, 1987). If attention deficits or under active neuromuscular response interferes with the function of either the spindles or the receptors optimum motor performance cannot be achieved. Calvo and Alamo concluded from their study arousal deteriorated the ability to perform a motor task. The gross-motor tasks did not suffer as greatly as fine motor tasks suggesting interference mechanisms are of muscular and attentional nature.

Lundberg, Forsman, Zachau, Eklöf, Palmerud, Melin, and Kadefors (2002) took their investigation beyond attention demands and more specifically into the neuromuscular aspect previously discussed. Instead, this investigation focused on how stress affects motor units and may promote the pain sensation generally associated with high stress careers. The theory that the same motor units are activated by stress and physical demands is to be examined.

The activity of the trapezius muscle was recorded throughout a sixty-minute period. Throughout the sixty-minute period, the subject performed several stressful tasks such as the Stroop color-word task and two forms of mental arithmetic. The stressors produced a moderate, but significant, increase in the muscle activity of the trapezius muscle, which was analyzed with an intramuscular electromyography, and also in heart rate, (Lundberg, 2002). The same muscles were recruited during arousal as during physical effort sustaining a consistent activation among low-threshold motor units. The continual activation of these low-threshold motor units could be another example of an attention demand as described by Calvo and Alamo (1987), which could promote less ability to perceive proprioceptive position by reducing neuromuscular control in fine motor tasks and detecting fine motor movement.

Proprioception Training

The ability to accurately perceive the orientation of the body within the environment is a complex and important process. Previous studies have investigated different means that improve this ability. Supposedly, training and practice can lead to more successful attempts when determining the position of the body or the body segments.

Individuals suffering from injuries have hope to improve their kinesthetic abilities. Laskowski, Newcomer-Aney, and Smith (1997) investigated several rehabilitative mechanisms to improve and restore proprioceptive abilities. Unfortunately only the results of proprioception can be measured, not the ability directly, but how training affects proprioception can be inferred. However, it can be assumed through training and rehabilitation, proprioceptive function can be maximized and protection from injury can be obtained.

To gain improvement exercises requiring conscious movements should be repeated several times both slowly and more ballistically, (Laskowski, 1997). Unfortunately, specific mechanoreceptors cannot be deliberately trained, but certain activities promote mechanoreceptor activity, which will affect the central nervous system pathway. With specific training, both the afferent and the efferent arcs can be fine-tuned allowing better proprioceptive function.

Balance training is also important for static activities, (Laskowski, 1997). To improve balance training using one-legged stands, wobble board stands, and defense from perturbation during standing is efficient. Sport specific exercises should, likewise, be used in athletes to create a "pre-program", which the athlete can refer to during sport activities. The pre-programming of the proprioceptive pathway necessary for producing the desired movement can be trained through practice and assist in accurate performance of the skill during sport performance.

Not only injured can benefit from training effects on proprioception. Euzet and Gahery (1995) investigated accuracy of determining the knee position in sportsmen, serving several years at the competitive level in various sports, and a control group, untrained individuals. Two types of tasks were performed, an intramodal test and a cross-modal test.

During both tests the subjects wore a goniometer on the knee to measure the joint angle. Two types of tests were performed: intramodal test and cross-modal test. The intramodal test requires the individual to replicate the knee angle from one leg to the contra lateral leg. The cross-modal test requires the subject to match an angle seen on a projection screen to the angle of the knee, visual-kinesthetic task, or the subject was asked to adjust the angle projected on the screen to match the angle of his own leg, kinesthetic-visual task, (Euzet, 1995).

Upon conclusion of the study, the sportsmen demonstrated less inaccuracy in replicating and producing desired joint angles about the knee, (Euzet, 1995). However, the reason for the increased ability to determine position sense among the sportsmen should be viewed as task specific. With the intramodal task, two hypotheses can be suggested for the increased proprioceptual ability. First, as sportsmen train the development of muscle fibers could be paralleled with the development of muscle sensory receptors. With more developed muscle sensory receptors, the ability to obtain more accurate information regarding position sense, in turn, increases linearly. Second, as sportsmen learn to perform a specific skill, more emphasis is placed upon proprioceptive control. As the need for improved motor activity increases in order to perform well in a competitive sport, the ability to better sense the body's position during performance of necessary motor tasks increases as well. The amount of practice the sportsmen have spent training for a specific sporting event has allowed them, in turn, to practice proprioceptive ability.

The cross-modal task requires the use of several cognitive processes and more complex transfers of the acquired information, (Euzet, 1995). Consequently, both the sportsmen and the control group demonstrated less accuracy in this test as opposed to the strictly proprioceptive test. The sportsmen still proved to be more capable than the control at sensing the angle of the knee.

The improved ability among the sportsmen in the cross-modal task can also be attributed to the learning process, (Euzet, 1995). The ability to better sense body position can be improved through practices that focus on movement results. During this type of practice, not only the final position is learned but also the activation and motion of the segments, even those segments not directly involved in the motor task. Sportsmen therefore have an increased chance to detect position sense in segments they may or may not use during competitive sport practices.

Based on the results of this study performed by Euzet and Gahery (1995), the more accurate ability of the trained sportsmen to detect position sense can be attributed to higher training. Training effects produce a better ability to perceive position sense. The ability to detect position sense and the relationship this study demonstrated between position sense and motor performance suggests through proper motor training position sense efficiency can be improved.

Fortunately, this study by Euzet and Gahery examining training and proprioception suggests proprioceptive abilities can be improved with practice. With this knowledge, an individual with decreased proprioceptive ability can improve upon his or her decreased ability to obtain better position sense detection. A better proprioceptive ability could prevent accidents due to proprioceptive, or position sense, deficits. For those suffering from or experiencing an increase in accidents due to lose in proprioception function, such as diseased or elderly individuals, proper training can improve these abilities significantly.

Previous studies have suggested stressors create a state of physiological arousal. Under a state of physiological arousal, an increase in heart rate and blood pressure exists. During the state of arousal attention is divided between numerous compensatory body responses and deficits are created in proprioceptive ability. Decreased ability to perceive body positions reduces the ability to perform accurate motor tasks, such as gait, stepping, driving, and sporting events. Deficits in proprioception can also increase the incidence of injury by hyper-extending a joint or over-rotating. Balance and coordination rely heavily on accurate proprioceptive information as well. With a lack of quality information on the orientation of the body segments and the muscular activity within those segments, which may occur under aroused conditions, balance and coordination may suffer.

METHODS

The purpose of this investigation was to examine how an increased state of physiological arousal resulting from a stressor protocol affects the ability of a healthy young adult to accurately perceive the location of an upper extremity in space. As young adults encounter stress producing physiological arousal, it is hypothesized the inaccuracy of upper extremity position sense will increase between the pre-test and post-test trials.

Prior to recruitment of research subjects, an application packet for research with human subjects was submitted to the University of Mississippi Institutional Review Board for the Protection of Human Subjects. The packet included a brief overview of the study, copies of the questionnaires presented to subjects, consent forms to be signed by each subject providing consent to participate in the research study, a copy of the recruitment flyer used to advertise the research study to potential subjects, and a summary of the procedure.

Participants

Following Institutional Review Board clearance, recruitment of subjects was initiated. Subjects were recruited from the Department of Exercise Science at the University of Mississippi in Oxford, MS. The subjects were scheduled to attend data collection in the Applied Biomechanics and Motor Control laboratory at the University of Mississippi. Each session was allotted thirty minutes. The subjects were all healthy, young adult students attending the university. The mean age of the participants was 22.3 years, spanning an age range of 20-33 years of age. All subjects reported being free of diagnosed vision problems, neurological disorders, and joint problems. No subjects reported experiencing a major negative life event within the last month.

Twenty experimental subjects underwent data collection. Of the experimental group, twelve of the subjects were female while eight were male. Nineteen of the subjects were right handed while one subject was left-handed. The subjects volunteered to participate in the study and received no compensation for their involvement.

All subject forms were kept in folders with corresponding subject numbers. The subject numbers were assigned based on the order in which the subjects were tested. The pre-fix for the subject number is YAEX, Young Adult Experimental, followed by position in the line-up, such as 01 for the first subject, 06 for the sixth subject, 11 for the eleventh subject, etc.

Procedures

During scheduled data collection sessions, subjects were first familiarized with the study. Questions were accepted, but not all questions could be answered prior to data collection due to the nature of the research study. Following familiarization, subjects completed necessary paperwork. The paperwork consisted of a form providing consent to act as a human subject. The consent form provided the subject with a brief explanation of the study, an overview of possible risks and benefits related to the study, a statement of confidentiality, a right to withdraw statement, a verification of IRB clearance to perform the research study, and a statement to consent as a human research subject followed by a dated signature from the subject and the investigator.

Also included in the paperwork was a participation and health history questionnaire. These forms provide the investigator with personal information regarding the subject, emergency contact information for the subject in the event an accident or emergency should occur during data collection, a brief medical history form to ensure the subject is a healthy young adult, medications being taken by the subject, and a health behavior history questionnaire to provide insight into how the subject responds and copes with situations involving stress and comfort levels while performing specific tasks, such as simple addition and subtraction problems. The self-evaluation questionnaire acquired from Devito and Kubis (1983) was also use to evaluate how the subject felt prior to performing research data collection. However, the information from the SAI will not be utilized until after control group data is collected.

Pre-Stressor Protocol Procedures

Upon completion of all required paperwork, the blood pressure cuff was placed on the upper segment of the non-dominant arm of the subject. Two electrodes were placed inferior to the clavicle, one on the right and one on the left side of the body. The remaining two electrodes were placed inferior to the rib cage, also one on the right side of the body and one on the left side of the body. Once the subject was properly connected to the Colin STBP-780 Automated BP system (Colin Corporation, Japan) heart rate monitor, the subject was allowed to relax prior to taking the first resting blood pressure.

Following several minutes of downtime, the first resting blood pressure and heart rate were measured and recorded.

The subject was lead to the 16014 Kinesthesiometer obtained from the Lafayette Instrument Company (West Lafayette, Indiana). The kinesthesiometer measures angular displacement along a 90-degree scale. The subject was instructed to place the dominant arm onto the saddle of the kinesthesiometer perpendicular to the subject's torso. Instructions were given to place the elbow on the black foam pad at the base of the saddle with the hand palm down and fingers falling comfortably over the finger guide pin at the opposite end of the saddle. The upper limb of the subject was positioned at zero degrees, neutral, according to the scale on the kinesthesiometer. The task was then explained to the subject.

The subject was informed they would move the dominant upper limb from the neutral position to a specific angular measurement announced aloud to the subject. The angle will be between the neutral position and 90 degrees. The investigator then moved the saddle with the subject's upper limb through the complete 90-degree motion from neutral to 90 degrees and back to neutral. This procedure was performed two complete times to allow the subject to form a sense of the area over which they will be traveling.

The angles to which the subject was asked to move in the pre-test were standard for all subjects. The sequence of the angles was randomly selected to prevent any practicing effect from occurring. The order of angles for the pre-test was: 75, 15, 60, 45, 90, and 30 respectively. The order of pre-test angles was kept consistent between all subjects to maintain experimental consistency and reduce error. However, the vision of the subject was occluded with non-transparent goggles. Subjects were required to rely solely on upper extremity position sense with no visual feedback. The angle to which the subject moved was recorded and used to compute an average absolute error score.

Stressor Protocol

The subject, after the pre-test, was directed to the computer for the stressor protocol. The Stroop color-word task and math sections were explained to the subject. During the Stroop color-word task the subject was instructed to key in the font color of the color word printed on the computer screen using the keypad. On the keypad, the numbers 2, 4, 6, and 8 were labeled with colored stickers corresponding to the color choices red, blue, green, and yellow. The subject was warned the word will read one color, be printed in another color, and another color will be suggested audibly, all representations of color being incongruent. However, only the color of the font should be entered. The first section of the Stroop color-word task will last two minutes followed by two minutes of simple math problems.

The math section involves subtracting a one or two digit number from a three-digit number as quickly and accurately as possible. The problems are timed and will only allow a short period for response before moving to the next math problem. The answer to the math problem had to be entered using the keypad and pressing enter; no backspacing was allowed. Once the two minutes of math problems was complete, the protocol repeats: two more minutes of Stroop color-word task and two more minutes of simple math problems. The entire stressor requires eight minutes for completion. Throughout the eight-minute stressor, external prompting from the research instructing the subject to respond quickly and accurately to the Stroop color-word tasks and the simple math problems was used to maximize arousal levels.

During the fourth minute, following the first set of simple math problems, heart rate and blood pressure were measured and recorded again. At this point during the stressor protocol the body's reaction to the stressor was best visible in the heart rate and blood pressure readings.

Post-Stressor Protocol Procedure

The subject was moved back to the kinesthesiometer immediately following the stressor protocol; arousal effects will only last up to two minutes. The same procedure performed in the pre-test was repeated in the post-test. The pre-set angles for the post-test were reordered to prevent a practice effect. The post-test angles were, in sequence, 60, 15, 45, 75, 30, and 90. Vision was again occluded with non-transparent goggles, and the subject used the dominant arm as before in the pre-test. The subject was asked to move to the respective, "desired", angle. The angle to which the subject moved was recorded as the "actual" angle. The "actual" angles were again recorded and utilized to produce an average absolute error score.

The goggles were then removed and one last heart rate and blood pressure was taken. To complete the research, the subject filled out the same SAI form completed before the study stating current feelings following the research and stressor protocol. The blood pressure cuff and electrodes were then removed. Questions were then answered and the goal of the Stroop color-word task and simple math problem protocol was explained to the subject. The subject was asked to keep the research procedure and aims confidential to prevent future subjects from gaining information regarding the study.

Data Analysis

The data obtained were then analyzed. The average for the pre-test "desired" angles and the post-test "desired" angles were calculated by adding the six angular measures from within each test together and dividing by the number of angular measures, six. The average of the desired angles for both the pre-test and post-test was 52.5 degrees; the same six angles were used in both the pre-test and post-test in a pre-determined sequence. The angles recorded on each attempt by the subject, recorded as the "actual" angle, were also added and averaged within each test, pre-test and post-test.

The absolute error score, the difference between the acquired average for each subject and the average score for the angles proposed to the subject, was then recorded. The absolute error scores were then entered into Microsoft Excel and analyzed using SPSS.

The heart rate and blood pressure recordings were also evaluated to illustrate a state of arousal. The average heart rate, diastolic blood pressure, and systolic pressure measurements were recorded for the pre, mid, and post tests for each subject. The averages of nineteen individual subjects were then averaged together to obtain one overall average for the pre, mid, and post test heart rate, diastolic blood pressure, and systolic blood pressure. Again, the averages of the pre, mid, and posttests were entered into Microsoft Excel and graphed for comparison. The average blood pressure recording form the pre, mid, and posttest measurements were also analyzed with SPSS software.

RESULTS

The data were analyzed using SPSS statistical data software. To prevent skewing of data subject YAEX 07 was omitted from all areas of the study due to abnormally high pre-test blood pressure measures. The subject admitted a state of increased nervousness due to the nature of the study. Data for the remaining nineteen subjects were analyzed.

Position Sense

The pre-test and post-test absolute error score averages were graphed against each other for comparison (Figure 1). The post-test results demonstrate a decrease in position sense accuracy while physiologically aroused. For analysis purposes, a significance level of 0.05 was selected. Evaluation of the differences between the pre-test and post-test absolute error score means revealed a statistically significant difference ($p = 0.02$).

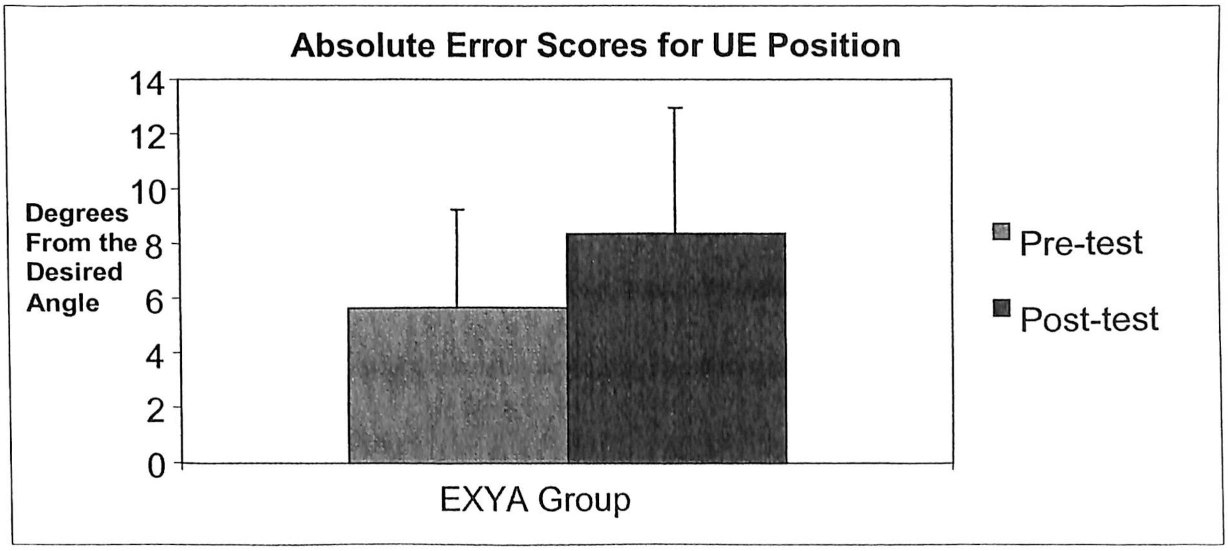

Figure 1: Position Sense Response to Stressor Protocol

Heart Rate

The heart rate recorded throughout the research sessions illustrates a state of physiological arousal. As states of arousal increase, the heart rate increases as well. The results obtained during the research sessions (Figure 2) suggest a relationship was present. Prior to data collection the heart rate was 72 ± 13 beats per minute. The mid-test heart rate was elevated to 81 ± 13 beats per minute and then decreased during post-test evaluation to 74 ± 14 beats per minute. A one-way repeated measure ANOVA was calculated comparing pre and mid-test, mid and post-test, and pre and post-test. A significant difference was found ($F=22.19$, $p< 0.017$). Dependent t-tests indicated heart rate scores increase significantly from pre-test to mid-test and decreased significantly from mid-test to post-test.

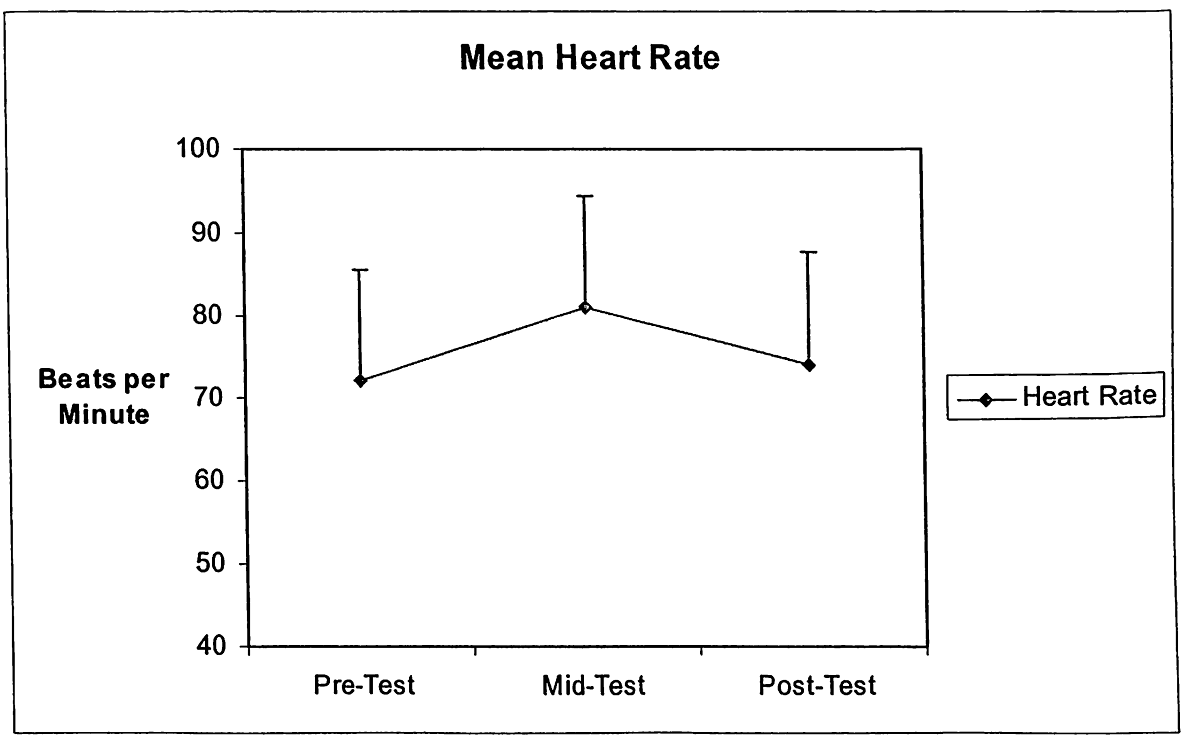

Figure 2: Heart Rate Response to Stressor Protocol

Systolic Blood Pressure

Systolic blood pressure (BP) is also an indicator of physiological arousal. The systolic blood pressure means were observed in three stages of data collection: the pre, mid, and post-test. The obtained means were 132 ± 16 mmHg, 135 ± 10 mmHg, and 132 ± 10 mmHg, respectively, for the pre, mid, and post test blood pressure measurements. The blood pressure measurements illustrate a climax during the mid-test recording (Figure 3). According to one-way repeated measures ANOVA, no significant difference was present between the pre-test, mid-test, and post-test ($F=1.85$, $p < 0.017$). Follow-up protected dependent t-tests also revealed no significant difference was present between pre-test, mid-test, and post-test means.

Diastolic Blood Pressure

Three diastolic blood pressure measurements were also recorded during the research sessions. A resting, mid, and a post-stressor blood pressure were all recorded. An increase in blood pressure measurements provides insight into states of physiological arousal. Pre, mid, and post stressor diastolic blood pressure means were 78 ± 9 mmHg, 88 ± 13 mmHg, and 80 ± 7 mmHg, respectively. The blood pressure means (Figure 3) illustrate a spike in diastolic blood pressure during the stressor protocol. The one-way repeated measures ANOVA was also used to compare the means in blood pressure at the pre-test, mid-test, and post-test intervals. A significant difference was found ($F= 14.26$, $p < 0.017$). Follow-up protected t-test revealed a significant difference between the pre-test and mid-test blood pressure means, and the mid-test and post-test blood pressures.

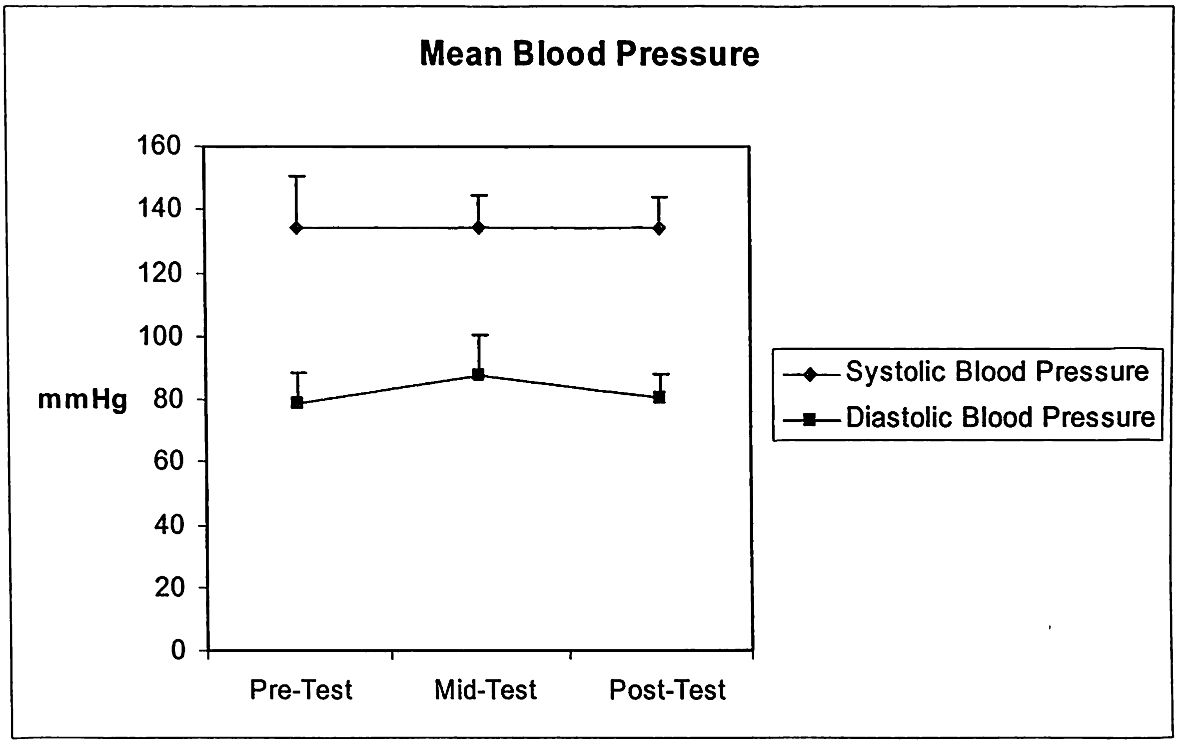

Figure 3: Blood Pressure Response to Stressor Protocol

DISCUSSION

The goal of this investigation was to determine how well a healthy young adult could perceive upper extremity position sense following a stressor protocol used to initiate a state of physiological arousal. One hypothesis was proposed prior to the implementation of the stressor protocol with heart rate and blood pressure recordings being examined to account for a state of arousal.

It was hypothesized an increased state of arousal will produce an increase in position sense absolute error between the pre-test upper extremity trials and the post-test upper extremity trials. The results of this exploratory investigation supported this hypothesis. The results revealed a significant difference between the position sense pre-test absolute error scores and the post-test absolute error scores. The increase in error scores following the stressor protocol suggests physiological arousal states do alter position sense perception.

It was hypothesized heart rate and blood pressure readings would demonstrate a state of physiological arousal during the stressor protocol and the arousal state would alter upper extremity perception. The results of the study revealed a statistically significant increase in three of the four measures examined in the study. Heart rates increased during the stressor protocol as did both systolic and diastolic blood pressure. The increase in systolic blood pressure was evident but was not of a statistically significant value. The absolute error also increased due to the stressor protocol. The increase in heart rate and diastolic blood pressure were both statistically significant. Cramer (2003) suggested in his study cognitive activities increase physiological arousal. The stressor utilized in this investigation used a stressor protocol comprised of cognitive activities, identifying the font color of a word and evaluating simple math problems. These cognitive activities can be associated with the significant increase in diastolic blood pressure.

Physiological Arousal Response

The physiological arousal response is due to an alteration in the central nervous system, (Cramer, 2003). The change is, however, mostly due to changes within the autonomic system, which affects the cardiac muscle, smooth muscle, and endocrine glands. The somatic system, affecting the efferent control of skeletal system is not directly affected. The autonomic response to arousal is an increase in both systolic and diastolic blood pressure. The increase in blood pressure is due to alterations within the parasympathetic and the sympathetic systems, which modulate the heart.

The increased sympathetic activity is associated with preparing the body for strenuous physical activity (PA) or stressful situations. As PA is initiated, the desire to increase the flow of oxygenated blood to the area involved in PA is created. In response to the increased desire for more oxygen, the heart rate increases, the blood vessels in the area constrict increasing blood pressure, and some systems, such as the digestive system and urinary system, experience minimal activity. This preparation for PA is commonly referred to as the fight-or-flight response. During the fight-or-flight response, norepinephrine and adrenaline are released, which reinforce the sympathetic response.

The increase in norepinephrine and adrenaline and the effects of these neurotransmitters on the body are indicators of physiological arousal.

The increase in blood pressure and heart rate the experimental group experienced characterizes a state of physiological arousal due to a response of the autonomic nervous system, specifically the sympathetic nervous system.

Position Sense Response

Based on acquired knowledge of the effects physiological arousal has on the autonomic system, it can be suggested position sense response is indirectly due to alterations in the sympathetic nervous system. No prior evidence suggests the parasympathetic system is altered, so muscular movement and activation is not effected by arousal but instead the sympathetic system involved in situations related to stress. During an aroused state, the body undergoes numerous physical changes regulated by the sympathetic nervous system: altering heart rate, constricting blood vessels, redirecting blood flow, and controlling the operation of body systems. As suggested by Calvo and Alamo (1987), as more stimuli are present the response to stimuli becomes more dispersed and less accurate.

Upper extremity position sense is important to carry out daily tasks. From brushing our hair and teeth to preparing and eating meals awareness of where the upper extremities are in relation to our body is significant. For younger adults maintaining independence is simple, but for the elderly performing tasks necessary to care for oneself may become difficult with decreased proprioceptive ability. Outside of gait problems, elderly could also experience difficulty showering and toileting if perception of the body is altered; elderly could slip or fall under such circumstances. Also, cooking and eating require accurate motor performance to move ingredients or food from one area to another. Situations initiating anxiety, walking from one room to the other or up and down a stairwell, or test anxiety, prior to performing a motor task can cause deficits in proprioceptive measures among the elderly, the former, or young adults, the latter. With decreased position sense, the ability to sense the relationship of these objects in relation to each other proves more difficult, not to mention the possibility of accidents while chopping ingredients while cooking. These daily functions rely on a functional ability to perceive the relationship of the body to the environment, and without the ability to perform daily function independence is lost, a major concern for elderly populations.

In this investigation the increase in inaccuracy supports the idea proposed by Calvo and Alamo (1987). The body is responding to the stressor, the Stroop color-word task and the simple math problems, by activating a response similar to the fight-or-flight response. As this response is initiated, attention is diverted away from the sensory information being received from the muscle spindles, joint receptors, and golgi tendon organs, and is instead accommodating for a stressful situation. With less attention on processing sensory information, the body cannot perceive upper extremity position as accurately. Although the attention designated to position perception decreases, the need for attention is stable and inaccuracy in movement results.

Future Investigations

The significant difference in pre stressor position sense trials and post stressor position sense trials provide a basis to continue investigating arousal effects on proprioception. The increase of upper extremity absolute error scores suggests a similar effect could be represented in lower extremity position sense as well. A deficit in proprioceptive ability in the lower extremity could promote difficulty stepping over an obstacle which could lead to falls during normal gait, an area of concern among elderly. Lower extremity position sense deficits could also lead to car crashes due to misconceptions of foot positioning between the brake and gas pedals, an important concern for all Americans as our main mode of travel is by vehicle.

The population investigated in this study was all healthy young adults. The use of healthy young adults reveals the effects of arousal on a normally functioning adult. In a diseased adult or an adult suffering from diagnosed vision or joint problems the effects of arousal on position sense may be magnified due to pre-existing deficits. Future use of older adults may provide better insight into the magnitude of proprioceptive ability loss in elderly. Older adults experience more stressors than young adults as elderly companions grow ill and pass on, social interactions decrease, prescriptions mount, and fears of losing independence progress. Elderly may not only respond more heavily to arousal but also have more exposure to stress. Regarding the baby boomer generation, implications of this study are applicable across a large population.

Concluding Remarks

As stated previously the ability to accurately perceive the relationship between our body and the environment is dependent upon proprioceptors within the body. These proprioceptors enable the performance of daily tasks, such as writing, normal gait, steering a vehicle, and participating in physical activity, to be performed precisely. As stressful situations are presented, the body responds with a state of arousal, which diminishes the ability to process upper extremity sensory information properly, as described in this investigation. Being the relationship between arousal and proprioception is due to alterations to the nervous system, the same adjustments can be assumed to occur in the lower extremity as well. Further investigations in this area should examine how arousal effects proprioceptive measures in the lower extremity and even further with an elderly population. The presently vast population of older adults could benefit from an investigation distinguishing how proprioceptive ability is decreased so a possible intervention could be established. With an intervention, gains in position sense could possibly be produced or losses in position sense could be prevented. With better position sense elderly could walk more confidently and, in turn, more successfully with less falls allowing elderly to be more functional and maintain independence longer.

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APPENDICES

APPENDIX A

THE UNIVERSITY OF MISSISSIPPI

Institutional Review Board for the Protection of Human Subjects

125 Old Chemistry
P. O. Box 907
University, MS 38677
662-915-7482 662-915-7577 (fax)
www.olemiss.edu/depts/research/irb

APPLICATION PACKET FOR RESEARCH WITH HUMAN SUBJECTS

This packet includes all forms and instructions needed for an IRB application for research with human subjects. Please indicate on the checklist below which items are included (or explain why they are not necessary for your study). The review process will not be initiated until the complete application is on file with the IRB, and research may not begin until approval has been granted.

Please submit the original and one copy of this form to
the Office of Research and Sponsored Programs at the above address.
Faxes are not acceptable.

CHECKLIST

- ☐ **Completed CHECKLIST and application (with appropriate signatures)**
- ☐ **Copies of all instruments/questionnaires**
- ☐ **Informed Consent form(s) – modeled after standard form on the IRB website**
- ☐ **Recruitment notices/announcements**
- ☐ **Debriefing statement and summary of procedure**
- ☐ **If conducting research off-campus, approval letter from other IRB(s) or Single Project Assurance(s) signed by the appropriate parties**

OFFICE USE ONLY:

Date Received ______________________________ Protocol No. __________

Investigator(s) ______________________________
____

Title ______________________________
____
____

THE UNIVERSITY OF MISSISSIPPI

INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN SUBJECTS

Protocol # __________ Date Received ______________

Application to Conduct Research with Human Subjects

1. **Title of Project: Effects of Physiological Arousal on Measures of Proprioceptive Feedback Control in Healthy Young Adults**

2. **Principal Investigator:** Dr. Christopher Kovacs
   Department Health, Exercise Science, and Recreation Management
   Work Phone 662-915-5567
   Mailing Address P.O Box 1848 Home Phone 662-234-0208
   University, MS. 38677
   E-Mail Address ckovacs@olemiss.edu Fax Number 662-915-5525

   Co-Investigator(s): N/A

4. **Funding Source** (if grant or contract): N/A

5. **Anticipated Beginning and Ending Dates of Human Subjects Contact:** Beginning Date (mm/dd/yy) 03 / 01 / 05 Ending Date (mm/dd/yy) 08 / 30 / 05

6. **Subject Characteristics**: Number 30 Age Range 18-26 (If under 18, parental consent required)

7. **Briefly describe subject population:**

As the goal of this proposed investigation is to examine differences in motor performance and position sense under conditions of increased arousal in young adults, it is anticipated that one group of individuals aged 18-25 will be used for this investigation. All participants will be healthy and free from significant neuromuscular and cardiovascular disorders.

8. **Special Risk Subjects Involved:** (Check all applicable groups)
   ❑ Pregnant Females ❑ Prisoners ❑ Elderly ❑ Fetal Tissue/Fetuses ❑ Mentally Ill
   ❑ Cognitively Impaired ❑ HIV+ ❑ Children/Adolescents ❑ Other ______

   ❑ Use of blood, other bodily fluids, or tissues (IBC approval needed. See Instructions.)

9. **Recruitment Procedures**:

All young adult participants will be recruited from students at the University of Mississippi through class recruitment and flyers posted around the Turner Building. Students may be given extra credit in classes for their participation in this investigation. This policy, however, will be up to the individual instructors and not guaranteed by the primary investigator.

10. Consent Procedures

☐ Information letter (attached) ☐ Informed Consent form (attached)

11. Where will the study be conducted? All data for this proposed investigation will be collected in the Applied Biomechanics and Motor Control Laboratory (Turner Center Room 245) on the University of Mississippi campus.

12. What are the possible risks (physical, psychological, social, work-related, financial, etc.) that might be experienced by the subject?

Participants may experience an increased feeling of frustration cognitively when completing the Stroop Color Word Task and mathematical problems. These tasks are designed to increase the arousal levels of the individual during their performance. There are no physical risks in participating in this investigation.

Specify the precautions that will be taken to minimize any risks.

All participants will be provided with the necessary rest periods between tasks to decrease the likelihood of fatigue effects. In addition, participants will be instructed that they are free to withdraw at any time.

13. What are the potential benefits, if any, to the subject? Explain:

Potential benefits include information about the performance of position sense under conditions of stress and the functioning of the neuromuscular system. Understanding one's neural capabilities and position sense (especially in the lower extremities) during activities such as walking and stepping may help prevent a chance of a fall occurring during their activities of daily living following the completion of the investigation. The ability to subconsciously assess one's position during movement is critical for the successful completion of any voluntary motor task.

14. What are the penalties, if any, the subject can experience from participation in the study? NA

15. How will you maintain subject confidentiality?

All participants will be assigned a participant number and will only be identified by that number during the investigation and in any subsequent publications. All data will be stored either in the primary investigator's office or in the Applied Biomechanics and Motor Control Laboratory. All raw data will be categorized by the participants ID and will not be linked to their name or other identifying characteristics. The primary investigator and one graduate student will be the only individuals with access to that information. Following the completion of the study, all data will be stored in the primary investigator's office for a period not to exceed 7 years. Following that time, all data will be destroyed.

16. Please attach a Project Description. Include a problem statement , brief literature review citing evidence for need of research, research design, data collection method, data analysis methods, and debriefing procedure and statement (if applicable).

See Narrative.

INVESTIGATOR ASSURANCE

Please read and sign below. Obtain signatures of your research advisor and co-investigators, if applicable, and of your department chair. Return this original and one copy, along with any attachments, to the Office of Research and Sponsored Programs. **Please allow up to four weeks for a response from the Office of Research and Sponsored Programs and/or the IRB. You will be contacted for any modifications and/or clarifications needed, and once approval is granted, you will be notified in writing. Approvals under the Expedited and Full Review categories are subject to continuing review by the IRB.**

I understand that no research activities should be conducted with human participants prior to obtaining the required approvals from the IRB. I will inform the IRB at the earliest possible date of (1) any significant changes in the project with respect to human subject participation, (2) any adverse reactions or unexpected responses observed involving human subjects, and (3) any need for continuation of the project activities beyond the approval date.

Failure to comply with Federal Regulations (45 CFR 46) can result in confiscation and possible destruction of data, suspension of all current and future research involving human subjects, or other institutional sanctions, until compliance is assured.

______________________________ ______________________________
Principal Investigator Date Research Advisor (if student project) Date

______________________________ ______________________________
Co-Investigator Date Department Chair Date

OFFICE USE ONLY: _______Administrative Review ______________________________
Office of Research Representative Date

_______Expedited Review* _______ Full Review*

____
IRB Chair Date

Narrative

The ability of an individual to sense one's body position in space is critical to efficient and safe human motor control. All tasks, including balance, gait, and functional tasks associated with activities of daily living require an individual to be able to obtain and process necessary sensory information through proprioceptive structures. Human proprioception (position sense) is made up of specific structures located within the human body, including joint receptors, muscle spindles, and golgi tendon organs. The goal of this investigation is to examine the effects of non-specific physiological arousal on the ability of joint receptors to provide accurate information during upper extremity movements (position sense). After an extensive examination of current and past literature, the research suggests that this specific question has not been addressed in the literature.

State anxiety is defined as an immediate emotional state that is characterized by apprehension, fear, and tension (Spielberger, 1975). Physiological arousal refers to the changes that occur within the nervous and cardiovascular systems when an individual is under increased stress. A recent investigation by Wada, Sunaga, and Nagai (2001) demonstrated that increased anxiety/arousal does alter performance of motor tasks in young adults. These investigators failed, however, to examine effects on position sense and proprioception. A recent review has suggested that examining attentional demands, such as increasing arousal levels, during functional tasks is an emergent area of study and should be extensively examined by investigators in our field (Woollacott & Shumway-Cook, 2002)

Individuals are often fearful and apprehensive when having to perform sudden, unexpected motor tasks, such as stepping over an obstacle, walking over uneven terrain, or making a sudden upper extremity position change, such as that required for safe automobile driving. This increase in apprehension, or level of physiological arousal, may increase the attentional demand during a motor task in a similar manner as that seen during simultaneous task performance and increase the likelihood of erroneous sensory information regarding joint positioning, this leading to possible incorrect movements or accuracy of movement. Decreases in position accuracy have significant implications for many populations, including older adults who may increase the chance of a fall if positioning sense is incorrect. Additionally, driving an automobile requires the individual to be able to react to external stimuli, such as an unexpected pedestrian or automobile, by moving their lower extremities as rapidly as possible to apply the brake following the stimulus. Thus, the goal of this proposed investigation is to examine the effects if increasing physiological arousal on position sense in tasks common to functional activities, such as driving an automobile and walking.

Research Design

All data will be collected in the Applied Biomechanics and Motor Control Laboratory on the University of Mississippi campus. Two groups of adult participants will be recruited for the purpose of this investigation. Each group will consist of approximately 22 individuals between the ages of 18-25. Each participant will be randomly assigned to either the experimental group or control group for the duration of this investigation using a pre-test/post-test design.

During the session, all participants will complete an informed consent and health history questionnaire designed to assess their health and motor function. Participants will be free from any major neurological or musculoskeketal conditions, be free from any significant cardiovascular condition, and must be generally healthy. Following the completion of all paperwork, each participant will be given a ten-minute period of time to relax and allow for any stress or anxiety to dissipate before data collection.

Data Collection

When an individual is psychologically stressed in an acute manner, a complex chain of reactions occur, stemming from responses occurring within the sympatho-adrenal (SA) and the hypothalamic pituitary adrenal (HPA) axes. Psychological stressors such as the Stroop Color Word task (SCW; Stroop, 1935), modified SCW tasks (Gerra, Zaimovic, Mascetti, Gardini, Zambelli, Timpano, Raggi, & Brambilla, 2001), and mental arithmetic tasks (MA) have been shown to cause physiological alterations in the body at rest (Dishman & Jackson, 2000; Sehested, Reinicke, Ishino, Hetzer, Schifter, Scmitzer, & Regitz, 1995; Shapiro, Jamner, Lane, Light, Myrteck, Sawadea, & Steptoe, 1996; Shapiro, Sloan, Bigger, Bagiella, & Gorman, 1994; Siconolfi, Garber, Baptist, Cooper, & Carleton, 1984; Spyer, 1989).

All testing sessions will include a modified Stroop Color Word (SCW) task (Gerra, Zaimovic, Mascetti, Gardini, Zambelli, Timpano, Raggi & Brambilla, 2001), which is a modification of the original SCW task introduced by Stroop (1935), and a mental arithmetic task (MA) involving subtraction of a 1- or 2-digit number (3, 7, 8, or 13) from a 3-digit number, will be used to induce psychological stress.

Participants will perform ten trials of the upper extremity motor task without prior arousal to obtain baseline measures. Following a ten-minute rest period, each participant will perform the same task following presentation of the SCW and MA stressors. Each participant will perform the Modified Stroop Color Word (SCW) task and a mental arithmetic (MA) task for approximately eight minutes prior to the performance of the motor task. Physiological arousal will be assessed during these tasks through heart rate and blood pressure monitoring. Physiological arousal should remain elevated for approximately two minutes, thus allowing for enough time for the completion of several trials of each motor task. Arousal will be increased through the SCW and MA tasks prior to each motor task to insure increased arousal levels.

Upper Extremity Motor Task

For the purpose of this task, each individual will be positioned in a seated position in front of an upper extremity angle transducer. This piece of equipment requires that individual to place their upper extremity (dominant vs. non-dominant) on the machine perpendicular to their upper torso, lightly gripping a small bar with their hand. Each individual will have their vision occluded (blindfold) and will be asked to rotate their upper extremity to a desired angular position. For example, they will be asked to "move their upper extremity 45 degrees from neutral (perpendicular)" and the difference between the desired position and the actual position will be recorded. They will perform ten trials for both their dominant and non-dominant upper extremity, each time performing a different angular change. These trials will be randomly ordered to account for any possible learning effects. Following the completion of the stressor task, these same angular changes will be performed to accurately assess pre to posttest change.

Data Analysis

Group differences will be examined for the measurement of error between the desired angular position and the actual angular position (DAP-AAP). Additional statistical analysis will examine differences between dominant and non-dominant upper extremity results. A repeated measures analysis of variance (ANOVA) will be conducted between non-arousal and arousal conditions for each variable. A $p<.05$ will be used for all statistical analyses. In addition, Pearson Product Correlation Coefficients will be performed between each variable to examine the relationships between each of the different factors.

APPENDIX B

University of Mississippi
Department of Health, Exercise Science, and Recreation Management

CONSENT TO ACT AS A HUMAN SUBJECT

Project Title: Effects of Physiological Arousal on Proprioceptive Function in Healthy Young Adults

Project Director: Christopher Kovacs Ph.D.
Assistant Professor
Department of Health, Exercise Science, and Recreation Management
University of Mississippi
(662) 915-5567

Participant's Name:______________________________ **Date of Consent:**____________

Purpose of the Investigation:

You are being asked to participate in an investigation designed to assess the effects of increasing feelings of stress/arousal on motor performance. Your participation will include you coming to the Applied Biomechanics Laboratory (245 Turner Building) for one testing session, which will last approximately 45 minutes. The following is an explanation of what you will be asked to do during your testing session.

During the session you will be asked to complete a brief medical history questionnaire and participate in a series of mental tasks. These tasks are a color-word task in which you will be instructed to identify the color of a word that may conflict with the word being presented and a series of math problems in which you will be asked to add or subtract quickly. In addition, throughout the testing session, you will be asked to complete a short questionnaire addressing how nervous you are and how hard you are working at the task. For the final component of this testing, you will be asked to perform a series of movements designed to assess your ability to "feel" where your upper extremities are in space. For this task you will be required to wear a blindfold to prevent any visual information from helping you. You will be seated in front of equipment designed to assess the change in arm angle during movement and will be asked to move the assigned arm various degrees while in a seated position.

Risks and Benefits:

There are no risks to participating in this study. You may feel slight frustration when completing the tests, but no physical risks are foreseen. In addition, you will be provided with as many rest breaks as needed.

Confidentiality:

A participant number will be randomly assigned to you. The participant number will be used in all situations in which you need to be identified. All written information will be kept in a locked filing cabinet in the office (Turner 232). Only members of the research team will have access to this information. Your name will not be associated with any written reports or publications.

Right to Withdraw:

You have the right to withdraw your participation in this study at any time during the research project. If you decide that you want to withdraw, you need only to inform Dr. Kovacs. Whether or not you choose to participate will not affect your standing within the Department of Health, Exercise Science, and Recreation Management, or with the University of Mississippi, and will not cause you to lose any benefits to which you are entitled.

IRB Approval:

This study has been reviewed by The University of Mississippi's Institutional Review Board for the Protection of Human Subjects (IRB). The IRB has determined that this study meets the ethical obligations required by federal law and University policies. If you have any questions, concerns, or reports regarding your rights as a research participant, please contact the IRB at (662) 915-3929.

Statement of Consent

I have read the above information. I have been given a copy of this form. I have had an opportunity to ask questions, and I have received answers. I consent to participate in the study.

Participant's Signature: ______________________________ **Date:** ______________

Investigator's Signature: ______________________________

APPENDIX C

Participation and Health History Questionnaire

Complete each question accurately. All information provided will be kept strictly confidential.

Part I: Participant Information

______________________________ ______________

Name **Home Phone #**

_______ ______________

Age **Work Phone #**

______________________________ ______________

Current Address **Personal Physician**

____

Emergency Contact Name and Phone Number

Gender: _______ Female _______ Male

Height: _______ **Weight:** _______

Part II: Medical History

Has your doctor ever said that you have a heart condition and/or that you should only do physical activity recommended by a doctor? Yes No

Do you feel pain in your chest when you do physical activity? Yes No

In the past month, have you had chest pain when you are not doing physical activity? Yes No

Do you lose your balance because of dizziness or have you ever lost consciousness in the past year?
Yes No

Do you have a bone or joint problem that could be made worse by a change in your physical activity? Yes No

Do you have any neurological (nervous) disorders that may impair your ability to do physical activity? Yes No

Is your doctor currently prescribing drugs for your blood pressure or heart condition? Yes No

Have you fallen for any reason in the past six months? Yes No

Have you sustained any broken bones in the past year? Yes No

Have you ever been diagnosed with vision problems? Yes No

Do you know of any other reason why you should not do physical activity? Yes No

Do you often feel "stressed" and have trouble controlling those feeling? Yes No

Do you often feel "numbness" or loss of feeling in your extremities? Yes No

If you answered *yes* to any of the previous questions, please describe below.

Medications:
Are you taking any medications (prescription/ non-prescription)?_____ Yes _____ No

If so, please list all medications.

Part III: Health Behavior History

Do you currently exercise? _______ Yes _______ No

If so, circle which types of exercise in which you currently participate?

Weight Training	Walking	Jogging
Bicycling	Swimming	Aerobic Dance
Yoga	Tai Chi	Dancing

Other: ____________________

How often do you participate in exercise activities?

1-2 times per week   3-4 times per week   5-6 times per week

Other: ________________

Have you recently (within 1 month) experienced a major negative life event (i.e. death in family, divorce)? Yes No

How would you rate your ability to add and subtract numbers?
______ Very capable _____ Capable ______ Not very capable

How would you rate your comfort level with adding and subtracting numbers?
______ Very much at ease _____At ease ___ Somewhat at ease _____Very uncomfortable

APPENDIX D

"Effects of Physiological Arousal on Measures of Proprioceptive Function in Healthy Young Adults"

Name:______________________________ Subject #: ________________________

Date of Test Completion: ____

Pre-Test

Desired	**Actual**
75°	_____
15°	_____
60°	_____
45°	_____
90°	_____
30°	_____

Post Test

Desired	**Actual**
60°	_____
15°	_____
45°	_____
75°	_____
30°	_____
90°	_____

*Desired: The degree to which the subject is asked to move.
*Actual: The degree to which the subject actually moves from neutral (0°).

Heart Rate and Blood Pressure Measures

Pre-Test: Heart Rate: _____________ Blood Pressure: _______________

Mid-Test: Heart Rate: _____________ Blood Pressure: _______________

Post-Test: Heart Rate: _____________ Blood Pressure: _______________

APPENDIX E

Heart Rate			
	Pre-Test	Mid-Test	Post-Test
YAEX01	98	113	113
YAEX02	53	60	50
YAEX03	60	75	62
YAEX04	59	70	70
YAEX05	84	89	74
YAEX06	76	84	71
YAEX07	55	70	64
YAEX08	77	84	80
YAEX09	85	93	92
YAEX10	73	92	75
YAEX11	83	81	84
YAEX12	70	74	65
YAEX13	90	90	81
YAEX14	62	65	64
YAEX15	84	95	90
YAEX16	--	--	--
YAEX17	70	88	74
YAEX18	53	66	60
YAEX19	72	77	72
YAEX20	84	92	75
YAEX21	57	62	64
Average	72.25	81	74

APPENDIX F

Systolic Blood Pressure			
	Pre-Test	Mid-Test	Post-Test
YAEX01	101	114	118
YAEX02	132	146	137
YAEX03	126	125	127
YAEX04	130	135	143
YAEX05	124	140	137
YAEX06	121	137	152
YAEX07	181	138	139
YAEX08	130	145	120
YAEX09	132	122	121
YAEX10	124	135	125
YAEX11	139	127	123
YAEX12	138	142	136
YAEX13	143	140	130
YAEX14	123	135	146
YAEX15	142	132	126
YAEX16	--	--	--
YAEX17	134	131	128
YAEX18	161	160	149
YAEX19	137	133	126
YAEX20	129	140	131
YAEX21	137	129	139
Average	131.7	135.2	132.3

Diastolic Blood Pressure			
	Pre-Test	Mid-Test	Post-Test
YAEX01	58	56	73
YAEX02	78	99	87
YAEX03	76	76	71
YAEX04	80	97	83
YAEX05	82	92	79
YAEX06	76	87	84
YAEX07	87	89	75
YAEX08	74	85	71
YAEX09	55	61	75
YAEX10	85	82	80
YAEX11	78	82	67
YAEX12	81	93	80
YAEX13	88	92	77
YAEX14	85	97	85
YAEX15	70	95	82
YAEX16	--	--	--
YAEX17	82	98	85
YAEX18	89	111	98
YAEX19	77	87	74
YAEX20	91	100	84
YAEX21	82	84	81
Average	78.3	88.1	79.5

APPENDIX G

	Position Pre-Test	
	Actual Angle	Absolute Error Score from Desired Angle Mean (52.5)
Subject		
YAEX01	55	2.5
YAEX02	50.3	2.2
YAEX03	56.8	4.3
YAEX04	50	2.5
YAEX05	54.8	2.3
YAEX06	52.2	0.3
YAEX07	52.5	0
YAEX08	47.2	5.3
YAEX09	62	9.5
YAEX10	45.5	7
YAEX11	46.7	5.8
YAEX12	56.5	4
YAEX13	45	7.5
YAEX14	63.5	11
YAEX15	40.7	11.8
YAEX16	--	--
YAEX17	52.7	0.2
YAEX18	47.3	5.2
YAEX19	46.8	5.7
YAEX20	42.8	9.7
YAEX21	42	10.5
Overall Average:	**50.5**	

APPENDIX H

	Position Post-Test	
	Actual Angle	Absolute Error Score from Desired Angle Mean (52.5)
Subject		
YAEX01	53	0.5
YAEX02	54.7	2.2
YAEX03	46.8	5.7
YAEX04	63.3	10.8
YAEX05	62.7	10.2
YAEX06	49	3.5
YAEX07	54	1.5
YAEX08	41	11.5
YAEX09	58.3	5.8
YAEX10	41.8	10.7
YAEX11	42.7	9.8
YAEX12	57	4.5
YAEX13	47	5.5
YAEX14	64.2	11.7
YAEX15	44.5	8
YAEX16	--	--
YAEX17	43.5	9
YAEX18	34.7	17.8
YAEX19	46.8	5.7
YAEX20	43.5	9
YAEX21	35.2	17.3
Overall Average:	**49.2**	