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ELECTROENCEPHALOGRAM ACTIVITY DURING VISUAL EXTERNAL, VISUAL INTERNAL AND KINESTHETIC IMAGERY OF A MOTOR PERFORMANCE

A Dissertation

Submitted to

the Temple University Graduate Board

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in Partial Fulfillment

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by

Celeste F. De Bease

January, 1989

ABSTRACT

ELECTROENCEPHALOGRAM ACTIVITY DURING VISUAL EXTERNAL, VISUAL INTERNAL AND KINESTHETIC IMAGERY OF A MOTOR PERFORMANCE

by Celeste F. De Bease

Doctor of Philosophy

Temple University, January, 1989

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The purpose of this study was to compare the relationship between three imagery conditions, visual external, visual internal, and kinesthetic imagery by means of electroencephalogram (EEG) brain wave activity. Specifically, this study was designed to determine if the three imagery conditions demonstrated differing topographic patterns of brain activation.

Thirty female softball players were randomly assigned to one of the three imagery conditions. EEG alpha rhythms from the occipital and sensorimotor regions of the brain were analyzed.

Topographic ratio scores ((O1+O2)-(C3+C4)/(O1+O2)+(C3+C4)) indicated that visual internal imaging had a greater relative sensorimotor component than visual

external imaging. The kinesthetic imaging condition fell between the two visual imaging conditions.

Differences between post-imaging relaxation EEG data and imaging data at both the occipital and sensorimotor regions were investigated across the three imaging conditions. No significant attenuation of alpha power was found in the occipital region. Only the visual internal imaging condition produced a significant attenuation of sensorimotor alpha. The results of this investigation suggest that during visual internal imaging of a motor performance, the sensorimotor region of the brain is activated and that a physiological, neurological distinction exists between visual internal and visual external imaging.

ACKNOWLEDGEMENTS

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My thanks are also extended Anna Cornwell, the EEG technician who was somehow able to make all these female subjects feel comfortable with having gobs of white paste applied to their scalps.

Thank you all.

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CHAPTER 1

THE PROBLEM

The use of imagery rehearsal of physical skills has been shown to improve physical performance (Corbin, 1967a; Noel, 1980; Vandell, Davis & Clungston, 1943). Controversy has arisen as to which imaging perspective, internal or external, will produce the most transfer of learning and which will produce the best results in improving performance. Internal imagery is characterized by a first person perspective and is thought to be essentially kinesthetic. External imagery, on the other hand, is thought to be predominately visual, with the person experiencing more of a spectator's perspective.

Electromyogram (EMG) studies have shown that neuromuscular patterns during imaging of the performance of a physical skill are congruent with the EMG patterns of the actual performance (Bird, 1984; Suinn, 1984). Harris and Robinson (1986) found that subjects using an internal imagery perspective during imagined right lateral arm raises produced greater EMG activity on the right side than on the left. No such results were found when subjects adopted an external imaging perspective. These findings have lent support to a general tendency to regard internal imaging as superior to external imaging because of the supposed kinesthetic component of internal imagery. Schmidt (1982) however, found that muscle innervation was not localized to the muscles involved in the physical task and that EMG patterns were secondary to overall arousal level.

Much of the literature on EEG and imagery deals primarily with visual imagery although imagery in 7 different modalities (visual, auditory, tactile, kinesthetic, taste, smell, body sensations) is thought to be possible (Sheehan, 1967). One of the strongest empirical finding in EEG literature is the attenuation of alpha waves in the posterior region of the cortex, the visual cortex, upon the production of a visual image (Shagass, 1972; Short, 1953; Slatter, 1960). Only recently have researchers turned their attention to the investigation of other imagery modalities. Modality specific imaging was thought to elicit predictable localized patterning of electroencephalogram (EEG) activity. Davidson and Schwartz (1977) studied EEG activation in the occipital and sensorimotor regions during visual and tactile imaging. They found that visual imagery elicited greater relative occipital activation than did tactile imaging.

As stated by Hatfield and Landers (1983) in their position paper entitled "Psycholphysiology - A new direction for sport psychology", rich methodological and theorectical insights can come from the psychophysiological study of mental imagery and motor performance. Yet, the advancement of scientific insight into the psychophysiological parameters involved with mental imagery can be slowed by ambiguities in essential terms. Properly defined, visual and kinesthetic imagery have to do with modality specific types of imagery. Visual imagery concerns itself with "seeing" an image; kinesthetic imagery deals with "feeling". Internal versus external deals with the imaging perspectives used when the individual is engaged in visual imagery. Very often, researchers seem to have equated visual internal imagery with kinesthetic imagery. If, when comparing visual internal imaging with visual external imaging, we instruct the internal imagers to feel the movements and sensations, are we not actually comparing visual imagery with kinesthetic imagery? Are not our results dubious? Is it visual internal imaging that causes more EMG activity or is it kinesthetic imagery that causes more EMG activity? If we had instructed the external imagers to feel the movements and sensations, would the differences between the two imaging perspectives still exist?

Perhaps we can say that a visual internal imagery perspective incorporates both visual imagery and kinesthetic imagery. Comparing the EEG measures of visual internal imagery, visual external imagery and kinesthetic imagery may provide a useful means for determining whether there is a kinesthetic component to internal imaging perspectives.

Statement of the Problem

The purpose of this study was to compare the relationship among three imagery conditions, visual internal, visual external, and kinesthetic imagery by means of electroencephalogram (EEG) brain wave activity. Specifically, this study was designed to determine if the three imagery conditions demonstrated differing topographic patterns of brain activation.

Hypotheses

The hypotheses formulated for this study were:

1. Imagery rehearsal of a motor performance will result in a reduction of alpha rhythms in the posterior region of the brain.

2. Different visual imagery styles, particularly internal versus external imagery perspectives, will result in distributional differences in alpha activity in the occipital and sensorimotor regions of the brain.

3. There will be greater relative occipital activation,that is, more alpha rhythm attenuation, for external imagery and a greater relative sensorimotor activation for internal imagery.

4. Kinesthetic imagery will produce greater relative sensorimotor activation than occipital activation.

5. Kinesthetic imagery will produce more alpha EEG activity, that is, more alpha rhythm attenuation, in the sensorimotor cortex than visual imagery (either internal or external).

Delimitations

The delimitations of the study were:

1. The population utilized in this study was not randomly selected. Only right-handed female softball players who were also right handed batters and who had played within the past two months and with a minimum of three years of active participation at an A or B softball league skill level were used.

2. Subjects were randomly assigned to one of the three imaging conditions.

3. EEG activity in the frequency range of 7.5 to 13 Hz from the occipital and sensorimotor areas of the brain was analyzed.

Limitations

The limitations of this study were:

1. This investigation must rely on a subjective evaluation of a person's mental activities and imagery style. There is no objective way to assess the subject's success at producing mental images.

2. Although subjects were instructed to use only one imagery style during a particular trial, they may have used

a mixed style. Thus, clear-cut results of the use of one style of imagery with changes in the EEG may be obscured.

3. Although the frequency range of the alpha wave is often thought to be between 8 to 13 HZ, the instrument used in this study (the Cadwell Spectrum 32) defines the frequency range as 7.5 to 13 HZ.

Definition of Terms

1. Alpha attenuation: Reduction of the amplitude of the alpha wave which is thought to be associated with cortical activation in the region displaying the attenuation.

2. Alpha power: A measure of the energy in the alpha frequency band over a particular period of time.

3. External imaging perspective: Visual imagery which is characterized by a third-person or spectator perspective in which images of oneself are seen from "outside" one's body.

4. Internal imaging perspective: Visual imagery which is characterized by a first person, phenomenological perspective in which images are viewed from "inside" one's body and the physical sensations associated with the imagined event.

5. Kinesthetic imagery: Imagery based on feeling the movement of one's body and the physical sensations associated with the imagined event.

CHAPTER 2

REVIEW OF LITERATURE

The purpose of this study was to compare the relationship between two visual imagery perspectives, internal and external, and kinesthetic imagery by means of EEG activity. The literature reviewed is presented under the following headings: (a) Paradigm Shifts in Mental Rehearsal Research, (b) Psychoneuromuscular Theory,(c) EMG Studies, (d) Cognitive-Symbolic Learning Theory, (e) Observational and Performance Outcome Studies, (f) EEG Studies and (g) Methodological Considerations.

One of the fundamental aims of the newly emerging discipline of sport psychology is to understand the underlying mental processes involved in athletic performance. If certain processing patterns emerge and can be causally related to outstanding skilled athletic performance, it may be possible to teach such patterns to participants in an effort to enhance the learning and execution of such skills. Mental imagery has been investigated for several decades as a potentially effective method for learning, integrating and improving motor skill performance.

Imagery or imagery rehearsal has been defined as "a covert activity whereby a person experiences sensory-motor sensations that reintegrate reality experiences" (Suinn, 1984, p. 24). Although many associate imagery with predominantly a visual modality, other modalities (tactile, auditory, olfactory) have been studied (Freeman, 1983). There is also speculation that no modality is exclusively used in any imaginistic exercise but that there is an overlap of multi-modal involvement (Sheehan, 1967; Slatter, 1960).

The studies of mental imagery has been carried out using a number of paradigms. Observational and performance outcome studies focus on correlates between imagery skills and criterion behaviors. More physiologically oriented approaches attempt to relate imagery phenomenon to indices such as EMG and EEG. Hatfield and Landers (1983) advanced the position that the examination of psychophysiological processes represents a new direction for sport psychology and a powerful tool for increasing our knowledge of the processes involved in motor performance. Research results have led scientists to formulate a theoretical basis for the demonstrated effects of imagery. Two such theories are the psychoneuromuscular theory and the cognitive-symbolic learning theory. Although the focus in much of the research has been to discredit one theory while advancing the other, some investigators have attempted to integrate both theories in a comprehensive explanation of mental imagery processes.

Paradigm Shifts in Mental Rehearsal Research

Mental rehearsal or mental practice is any form of covert practice that is performed with the specific intent of learning or improving a skill. It includes imagery rehearsal in which images are the mental medium used when rehearsing.

Early research in this area focused on the effects of mental practice on the performance of a motor task. Vandell (1943), who was probably the first to study the effects of mental practice on the acquisition of a motor skill, used a now classical experimental design. Three groups were used: physical practice only (PP); mental practice only (MP); and a no practice (NP) condition. Results indicated that "daily mental practice of a motor skill results in improvement in the later actual physical performance of that particular motor skill to such an extent that mental practice appears as effective as actual physical practice" (p. 247).

This task-oriented approach to the study of mental practice has yielded an extensive body of knowledge. As presented in Corbin's (1972) review of mental practice, researchers have addressed such issues as optimum combinations of mental practice/physical practice, optimum skill level, type of skill activity (i.e., cognitive/motor), and type of instructional set. Most of the mental practice studies have verified the following: (a) a 50 to 50 combination of MP/PP seems better than 100% of either (Clark, 1960); (b) subjects with higher skill levels improve with MP while low-ability subjects fail (Noel, 1980); (c) prior experience with the task seems essential. Novel tasks usually do not improve with MP or improve only marginally (Corbin, 1967a; Corbin, 1967b); (d) active imagery (i.e., imagery accompanied by the physical motions involved in the task) and kinesthetic imagery (i.e., imagery which stresses the bodily feelings and sensations associated with the task) seem to enhance the physiological responses of the imaging experience and may result in better performance than passive MP (Bauer & Craighead, 1979; Harris & Robinson, 1986; Ziegler, 1987); (e) performance improvement takes place predominantly within the cognitive or symbolic aspects of motor skills rather than the motor element when the task has a high cognitive component (Ryan & Simons, 1983; Sackett, 1934).

In the 1960s, some researchers began to change the way in which they tackled the mental practice issue. A new emphasis emerged which focused on the kinds of mental processes occuring as the individual performed and learned a motor response. Adams' (1971) closed-loop theory and Schmidt's (1975) schema theory are two such examples.

With the advances made in the fields of kinestheology, psychophysiology, and neurology as well as the availability of more sophisticated physiological measuring devices, a new shift has been emerging since the 1980s. Much research now focuses on the physiological concomitants of mental rehearsal. Studies measuring EMG and EEG are beginning to emerge (Harris & Robinson, 1986; Hatfield, Landers & Ray, 1984; Weinberg & Hunt, 1976). Hatfield and Landers (1983) view psychophysiological recordings as "process" research. They explained that "process research refers to the study and identification of the underlying causes of performance, whereas outcome research examines the resulting performance as a consequence of different treatment groups" (p. 247).

Psychoneuromuscular Theory

Research into the phenomenon of imaging in movement began in the early 1900s and was set against the backdrop of decades of inquiry and speculation about the nature of imagination in general. Perhaps the most central question revolved about the differences/similarities between perception and imagination. The speculative writings of Washburn (cited in Corbin, 1972) during the early 1900s proposed that imaginary and real sensations are basically the same except that imaginary sensations are of less magnitude. She suggested that when one images a motor movement, muscular activation of slight magnitude actually occur.

A more rigorous, empirical inquiry regarding the role and effect of imagery of muscular activity began with the work of Jacobson in the early 1930s. Jacobson was able to show that the changes in EMG muscle activity during imagery corresponded to the nature and specific content of the image. When subjects were instructed to imagine bending their right arm, action-potentials appeared from the right arm muscles. Although the magnitude of muscular activity was minute in comparison to that of the overt movement, Jacobson concluded that mental activity of a physical movement was not confined to closed circuits within the brain, but that neuromuscular regions were activated as well. Jacobson found that "when an individual imagines a movement, actual muscular activity is produced" (p. 549).

In regard to imagery rehearsal of a physical skill, it was believed that mental practice was actually activating and, in effect, training the very muscles that were involved in the physical skill. This explanation, which was an outgrowth of the ideo-motor principle, was later termed the psychoneuromuscular theory. It posits that minimal or low-gain neuromuscular efference patterns during imagined movement should be identical to those patterns generated during the same overt movement but reduced in magnitude. Eccles (1958) supported this theory by providing evidence that minimal firing of neural pathways associated with imaging a movement lays down a mental blueprint that helps to develop and strengthen the subsequent execution of the actual movement.

Corbin (1972) postulated that the muscle innervations involved in imagery may provide kinesthetic feedback aiding in improving future trials of an overt motor skill. The idea that proprioceptive feedback generated during imagery serves as the underlying mechanism for motor learning and performance enhancement is an extension of the closed-loop theory of motor learning. Although numerous closed-loop theories of motor learning exist, they all share the essential feature of providing for the receipt of feedback which serves to modify and correct subsequent behavior. The closed-loop theories of motor learning were developed in accordance with the cybernetic theory of information processing. Closed-loop theories are often called "inflow" explanations of learning since the underlying mechanism is based on feedback.

The psychoneuromuscular theory is often thought of as a type of closed loop theory that relies on kinesthetic feedback. A seemingly logical extention of the psychoneuromuscular theory seemed to be that the greater the kinesthetic component of imagery, the greater the benefits. Because of this, the imaginer's perspective, whether internal or external, was thought to produce different effects. An internal imagery perspective is characterized by a first person, phenomenological perspective and is thought to involve seeing and feeling the skill from the performer's perspective. Because it is thought to be potentially kinesthetic in nature it is often referred to as kinesthetic imagery. External imagery, on the other hand, is thought to be predominantly visual, being characterized by a spectator's perspective. If internal imagining is accompanied by greater somatic and sensorimotor activation when compared with external imagery, it may be the more efficacious method for the learning and subsequent performance of motor skills.

EMG Studies

EMG is a method of recording the electrical currents generated in an active muscle. Jacobson's (1931) work was the first to scientifically demonstrate, using EMG traces, that actual muscular activity does occur during imagery of a motor movement. In his classic experiments, imagination of activity of right arm movement was accompanied by contraction of the muscle fibers in that arm. Yet, a number of questions remained. Were the innervations localized only to the right limb on which Jacobson placed electrodes or was the excitation generalized to the entire body and a consequence of overall arousal? Was Jacobson's "muscular imagining" analogous to an internal imagery perspective? Does proprioceptive feedback generated during imagery practice serve as the underlying mechanism for skill learning and improvement? Is imagery, whether internal or external, causally related to better motor performance?

EMG studies have produced mixed results and conflicts over the interpretation of results. Both Bird (1984) and

Suinn (1984), using case studies of elite athletes, found that the EMG traces taken during imagery paralleled the event being rehearsed.

Schmidt (1982) found that the muscle innervation was not localized to the muscles involved in the physical task and he postulated that the performer is "merely preparing for action, setting the arousal level, and generally getting prepared for good performance" (p. 520). Harris and Robinson (1986), however, found a significantly greater amount of muscle activation in the arm involved in an imagined movement. What may be crucial to whether or not localization occurs is the imagery perspective.

Research has indicated that only internal imagery produces muscular efference (Hale, 1982; Jacobson, 1931). In the Harris and Robinson study (1986), no differences were found between EMG patterns from either arm under the external imagery condition. Only when an internal perspective was used did differences occur. Referring to the Harris and Robinson study, Hale (1986) noted that "the crucial importance of this study is that it is the first one to strongly demonstrate a verifiable localization effect during imagery, thereby supporting the possibility of a neuromuscular feedback explanation of mental imagery" (p. 348).

Yet, Kohl and Roenker (1983) found evidence that a proprioceptive feedback explanation was not substantiated. In research on unilateral and bilateral transfer during imagery practice involving a photoelectric pursuit rotor, no differences were found. They proposed that since transfer to the contralateral limb did occur, an outflow-based mechanism was involved, that is, that cognitive factors rather than neuromuscular activations play a primary role in mental skill imagery.

Cognitive-Symbolic Learning Theory

The cognitive-symbolic learning explanation for the benefits of mental rehearsal posits that imagery training gives the performer the opportunity to rehearse the sequence of movements as symbolic components of the task. According to this theory, motor performance learning occurs because cognitively coded information is built in a memory bank which stores information regarding the task specifications. Imagery facilitates motor performance only to the extent that cognitive factors are inherent in the activity. Rather than depend on proprioceptive feedback as an underlying mechanism in learning, programmed cognitive operations are thought to be responsible for the learning effect produced by imagery rehearsal. The cognitive-symbolic learning theories are often called "outflow" explanations of learning since they do not depend on peripheral feedback in the learning process. Rather, motor learning was thought to result from cognitive motor or symbolic programs generated during the skill acquisition phase. The first researcher to propose the symbolic learning theory with regard to motor performance was Robert Sackett in 1934. In an experiment involving maze learning, Sackett suggested that the benefits of mental rehearsal were derived not so much from the acquisition of muscular patterns as it was from ideational learning.

Morrisett (cited in Corbin, 1972), divided motor learning into 3 basic skill dimensions: symbolic, perceptual and motor. His investigations showed that mental practice improved performance on tasks that emphasized symbolic or ideational learning but had little effect on tasks high in the motor component. Results of Ryan and Simons' (1983) research were in accord with Sackett's theory. They concluded that imagery rehearsal effects are primarily associated with cognitive-symbolic rather than motor elements of the task. They found that subjects involved in a high motor task did not benefit from mental rehearsal. The mental practice group did not differ from the "no practice" group. Only when the cognitive factors of a task were high did the mental practice group differ from the no practice group. They found no evidence of motor elements being learned through mental practice. Ryan and Simons speculated that the benefits of mental practice are manifested because cognitive representation of the behavior were formed. Thus mental rehearsal acts as a type of modeling, only the form is covert rather than overt.

Minas (1978) found that rehearsal of the symbolic component of a motor task were primarily responsible for the performance improvement in her study. An analysis of improvement in the motor skill of throwing balls into a bin showed no difference between the mental practice group as compared with the physical practice group. Yet superior gain was made in the mental practice group's symbolic learning. This involved learning the "correct" target bin in which to throw the ball.

Schmidt (1975) developed the schema theory to explain motor learning. It was a refinement of the motor program aspect of the cognitive-symbolic learning theory. According to this theory, every movement must not have a separate motor program associated with it as the original forms of the outflow explanation stated. Rather, schema or sets of rules are abstracted each time a movement is produced. Skilled motor learning, according to the theory, is not the consequence of an exact replication of a previous movement but depends on a combination of cognitive operations that register (a) information received prior to the initial movement, (b) response specifications,(c) sensory consequences of the response and (d) knowledge of results after the movement is executed.

Feltz and Landers (1983) performed a meta-analysis on 60 studies on mental rehearsal and corroborated the results of Ryan and Simons (1983). They found that cognitive tasks had much larger effect sizes than tasks that were essentially motor or involved strength. They proposed that a cognitive-symbolic rather than a psychoneuromuscular mechanism was primarily involved in mental rehearsal.

Observational and Performance Outcome Studies

Start and Richardson (1964) investigated the effects of imagery vividness, controllability and modality on performance in a physical skill. Thirty-two male subjects mentally practiced a novel gymnastic movement for six days. The performance criterion score was based on the subject's first attempt to perform the movememt. Although they found that neither vividness nor controllability of images predicted performance outcome, the use of kinesthetic imagery was a factor in success at the criterion skill.

Suinn (1976), who developed an imagery technique called visuo-motor behavior rehearsal (VMBR) directs his clients to use an internal imagery perspective when mentally practicing their skills. He describes the imagery rehearsal he uses as "more than visual. It is also tactile, auditory, emotional and muscular...without fail, athletes feel their muscles in actions as they rehearse their sport" (p. 256). Suinn (1984) found that his method of imagery rehearsal, which incorporates an internal perspective, enabled athletes to significantly improve their performance in a number of motor skills.

Mahoney and Avener (1977), in an exploratory study of the psychology of the elite athlete, found that the orientation of imagery in successful Olympic gymnasts (that is, those that made it to the finals) was predominantly internal as opposed to external. In their study done with advanced karate students, Harris and Robinson (1986) found that more than three-quarters of the students favored an internal imagery perspective.

Epstein (1980) studied this area and found no solid evidence to demonstrate that internal imagery resulted in better motor performance on a dart throwing task. What Epstein did find, however, was that the male subjects who reported tactile imagery were more skilled at the dart throwing task and that many external imagery items on an imagery assessment questionnaire were negatively correlated with dart throwing performance.

EEG Studies

Physiological measures of the electrical activity of the brain present a powerful and objective record of cortical processes which are not accessible through self-report psychometric instruments. An EEG is "a visible record of the amplified electrical activity generated by the nerve cells of the brain" (Tyner, Knott, & Mayer, 1983, p. 1). In translating the word from its Greek roots, it means: electro-electrical; encephalo-brain; gram(ma)- picture. Thus, an EEG is an "electrical brain picture".

History of EEG

Late in the 18th century, Luigi Galvani, an Italian physiologist, demonstrated that the severed limbs of a frog