Brain Behavior is Related to Motor Behavior During Competition

Elizabeth Thorpe
Mentor: Dr. Bradley D. Hatfield
Associate Mentors: Jeremy Rietschel and Michelle Costanzo
School of Public Health, Kinesiology
University of Maryland, College Park

Abstract

In this study the alpha band waves of low to moderately skilled pistol shooters are evaluated to examine the performance of the individuals under a competitive environment. The factors that cater to success in the autonomous stage of learning are different for the athlete. There has been investigation of the brain patterns of experts, while performing a task is efficient and in accord with Fitts and Posner's claims of what it takes to be successful while in the last stage of motor learning (Hatfield & Hillman, 2001). The problem being addressed in the study is examining Fitts and Posner's cognitive stage of motor learning. The first question being studied is how does low alpha power relate to variability in the performance of a pistol shoot? The second question being studied is how does high alpha coherence relate to jerk in the performance of a pistol shoot? The first hypothesis to prove is that higher cortical arousal (i.e. lower alpha power), will be associated with better performance (i.e., less variable pistol trajectories). The second hypotheses to prove is networking to the motor planning region (i.e. higher coherence) will be positively associated with increased levels of jerk. The results of the study find that those who performed better (less variability and more jerk) exhibited brain patterns associated with relying on external cues, events and responses.

Problem Statement

The problem being addressed in the study is examining Fitts and Posner's cognitive stage of motor learning. Such that, we would expect cortical dynamics associated with actively guiding behavior to be associated with increases in performance. We also expect that cerebral cortical activity will be positively related to fine motor (target shooting) performance. Further, consistent with the neural efficiency hypothesis, we would expect increased effort (more cortical arousal and networking to the motor planning region) to be associated with more work (i.e. better performance) in relation to the low to moderate skill leveled test subjects. Another problem being addressed is how is the frequency of alpha band waves in the brain related to shot performance in relation to variability and jerk?

During the cognitive stage it is necessary to rely on external cues and explicit guidance of movement (Fitts and Posner, 1967). In contrast, during the autonomous stage, successful task completion relies on more internal models. Such that, when experts engage in an external focus their performance is compromised. When elite athletes perform under stressors and have noise added the system they can partake in an action that is referred to as choking. According to Baumeister's (1984) definition, chocking is when a pressure is applied to the circumstance and the performance decrements and pressure is considered any factors that place a significant importance on performing well. Causes that factor into chocking include self-talk and excess rumination. This can "cause performance degradation by generating nonessential brain activity and interfering with task-specific attentional and motor process" (Hatfield & Kerick, 2007, p.92). Studying the stages of learning by Fitts and Posner will give more insight into the functions of individual in the cognitive stage of motor learning. This problem is being addressed to contrast the information and research on elite athletes and how the novice athlete is expected to have different neurological functions.

Research Questions and Hypothesis

This section will discuss the research questions of the study as follows. In the study being performed competition is a proxy for stress perturbation. The addition of competition is the venue for the experiment allowing the researchers to record the effects of the competition in relation to alpha band waves. The first question being studied is how does low alpha power relate to variability in the performance of a pistol shoot? The second question being studied is how does high alpha coherence relate to jerk in the performance of a pistol shoot? The following study is being done to prove or disprove the following hypotheses. The first hypothesis to prove is that higher cortical arousal (i.e. lower alpha power), will be associated with better performance (i.e., less variable pistol trajectories). The second hypotheses to prove is networking to the motor planning region (i.e. higher coherence) will be positively associated with increased levels of jerk.

Definitions

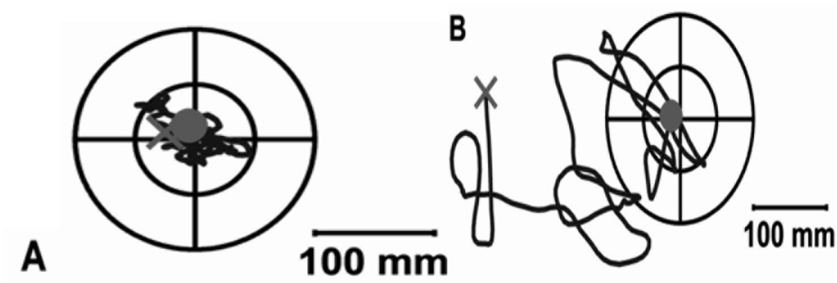
When reading the literature some terms are used in explicit ways that cater specifically to the study that is being conducted. This same notion is applied to the study that is being conducted for this research. The terms that are specific to this experiment are as follows.

Electroencephalogram (EEG). An EEG is a test that is conducted by a doctor to measure the electrical activity of your brain during the activity that you are performing. To give an EEG, sensors are attached to your head (sometimes the subject wears a cap that the sensors are attached to) and the sensors are then hooked to wires that connect to a computer. The computer records the brains electrical activity. These recordings look like wavy lines put down on a piece of paper. The wavy lines of electrical activity captured by the EEG are then interpreted to give results of the test (Rhodes, 2009).

Alpha Band Power. In this experiment the alpha band power are the band waves that are being studied from the EEG's collected from the brain during the designated task of shooting. The alpha band wave ranges from 8hz-13hz. The lower component of alpha waves (8-10hz) is characterized to be representative to changes in the overall arousal of the brain. The higher component of alpha waves (10-13hz) is characterized by representing task-specific arousal and/or "relaxation" of the brain (Klimesch, 1999 and Smith et al., 1999 in Deeny, Hillman, Janelle, and Hatfield, 2003).

Performance Accuracy. All test shots are based on the performance outcome. There is a preset target that subjects shoot at and the subject's shots are evaluated with the variables of score, variability, and jerk. Figure 3 is an example of a good and bad shot.

Figure 3



Shot A is a good shot and shot B is a bad shot.

Coherence. Coherence is the interconnection of the parts of the brain and their relationship to other aspects of performance. According to Deeny et al. (2009), "coherence values indicate the magnitude of correlation between the respective amplitudes derived for a given frequency (or band) from the two time series" (p.107). According to Weiss and Mueller (2003) the high coherence in an individual implies communication between areas of the brain. It is also stated that the low coherence implies regional autonomy.

Jerk. Jerk is the ability to make rapid movements in an effort to stay on target when making a shot.

"Noise". In the study being executed, the EEG captures brain waves that are relayed to the computer as lines. These lines are then deciphered to be brain waves of different nature like alpha, theta, and gamma brain waves. The intensity of the various different brain waves is referred to as "noise" in the brain. According to the Centre of Geriatric Care on ScienceDaily stated on July 7, 2008, the "brain noise is a term that has been used by neuroscientists to describe random brain activity that is not important to mental function." The "noise" in the brain referred to in this study is supported by the literature from ScienceDaily.

Significance of Research

The common person is interested in the elite athlete. When individuals start to learn a motor task they generally are not good at it. The elite athlete has had the time and experience to make themselves an expert at a certain motor task. The media captures the motor skills of elite athletes when they are performing. Examples of this are the National Football League, professional chess tournaments, Nascar, and even the Olympics. The general public is not, however, as fascinated with the individuals and athletes that have not yet reached the autonomous stage of motor learning. With this acknowledgement, it is important to focus on the individual who is in the cognitive stage of motor learning. All individuals who learn a motor skill have to start in the cognitive stage before they progress up the pyramid of motor learning. There has been investigation of the brain patterns of experts, while performing a task is efficient and in accord with Fitts and Posner's claims of what it takes to be successful while in the last stage of motor learning (Hatfield & Hillman, 2001). There has been very little investigation into the individual that is performing in the cognitive stage of motor learning. This stage of motor learning is important to understand so researchers, coaches, and the individuals performing in motor stages above the cognitive stage have background on what it takes to learn a motor skill. It is also important to study the cognitive stage of motor learning because people will be able to provide the successful novice/beginner learner with the proper environment and tools that are essential to being successful in the cognitive stage of learning.

The field of sports psychology is a fast developing field of study that examines the social and neurological characteristics that are related to sports and skill level. The significance of the research done in this study focuses on the neurological happenings occurring in the brain during a specific task required in shooting a target in athletes that are all engaged in the same motor learning stage. The findings from the study can be helpful in finding relationships between the cortical activity in the brain during the performances that are considered successful and non-successful. The findings from the research can be used to give support to what the individual in the cognitive stage engages in to be successful. This study will either support or oppose the activities that Fitts and Posner said that the novice athlete has to engage in to be successful.

Assumptions, Delimitations, Limitations, and Scope

Assumptions of the experiment are that the test subjects have all had the same amount of experience and are all on the same skill level. The subjects are starting at the same skill level based on the selection criterion. Any differences recorded were attributed to environmental manipulation. Test subjects are all in the cognitive stage of motor learning.

This study is not focused on the other frequencies that are present in the brain because alpha power is the primary measure of interest. The study does not take different skill levels into consideration as a variable since all the test subjects are in the cognitive stage of motor learning.

Limitations of the study have been set by using EEG to record the brain frequencies. The spatial resolution of an EEG is said to be relatively poor because "of volume conductions, or the spreading of electrical charge through out the liquid medium of the brain so that the signal is also detected by sensors beyond those overlying the region of interest" (Hatfield & Kerick, 2007, p. 88). The EEG has poor spatial resolution which makes it hard to tell regional specificity as confidently as fMRI. Another limitation to the study in relation to the research question is that with time constraints the researcher was not able to evaluate all aspects of the study and all sets of datum.

The scope of the study is set to the subset of the data that was analyzed to address a specific research question. The total experiment has been ongoing for numerous years but for the sake of the research questions only a portion of the experiment is analyzed. Another aspect of the scope is the time constraint that the Ronald E. McNair Post Baccalaureate Achievement research program has put on the McNair Scholars.

Literature Review

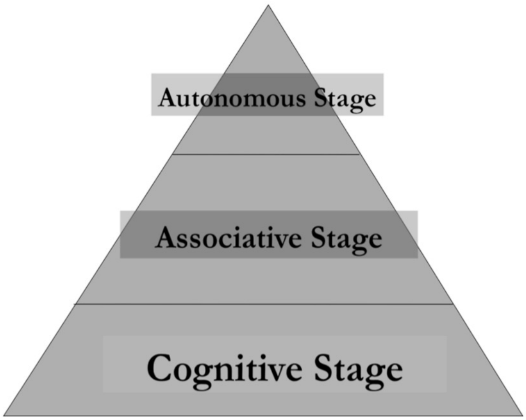
Many experiments have been done to test the relationship between the functions of the brain and the results of performance in the autonomous stage of motor learning. This does not stand true the cognitive stage of motor learning. The literature based on neurological functions and its relationship with athletic performance varies depending on what variables are being tested. The literature that focuses on alpha band power brain frequencies and accuracy of performance is rich and supportive.

Stages of Learning

Athletes and individuals are not born being an expert at any motor task. From learning how to walk, to throwing a baseball, to hitting a home run, we all progress from one stage of motor learning to another to become better at executing that task. Fitts and Posner proposed the stages of motor learning in 1967. The beginning stage of motor learning is the cognitive stage, the second stage of motor learning is the associative stage, and the final stage is the autonomous stage of motor learning. Figure 4 is an example of the stages of motor learning. During the cognitive stage it is necessary to rely on external cues and explicit guidance of movement. In contrast, during the autonomous stage, successful task completion relies on more internal models. Such that, when experts engage in an external focus their performance is compromised. EEG evidence in experts supports Fitts and Posner's claims about the autonomous stage. Less task-irrelevant activation and networking both crosssectionally, experts compared to novices, and longitudinally, individuals learning a task.

This is also consistent with the neural-efficiency hypothesis. Less effort is associated with more work. However, if individuals are in the cognitive stage the cortical processes that are irrelevant in experts may be essential to novice performance. Thus, we would predict increased cortical arousal in areas associated with task production as well as an increase in networking between task relevant areas and the motor planning region to be associated with increased performance. This is not in conflict with the neural efficiency hypothesis, although when there is more effort put forth, there is also a concomitant increase in the amount of work (i.e. increased performance).

Figure 4



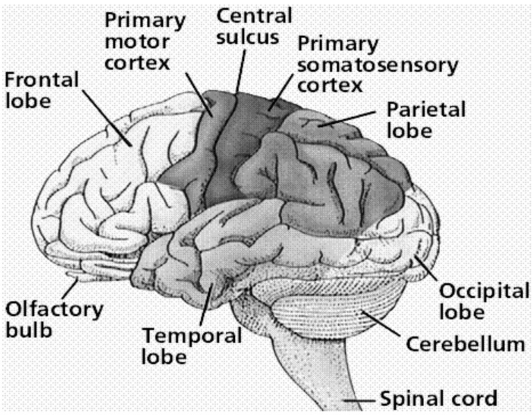
Fitts and Posner's stages of motor learning from the beginner cognitive to the later autonomous stage.

Parts of the Brain

One of the most popular ways to record cortical activities is using the EEG. EEG basically means "electrical brain writing" (Springer & Deutsch, 1947, p. 74). One of the first rhythms to be recorded is alpha power rhythm (Springer & Deutsch, 1947). Neuroscientists have done ample amounts of research to study areas of the brain and conclude that brain areas are task specific. Different regions of the brain are used during specific activities and all areas of the brain relate to each other differently. Scientists have performed many split-brain experiments where the corpus callosum in the brain has been severed. From these experiments researchers were able to study how the individual is affected when the two different hemispheres are not connected. It was found that the left hemisphere is responsible for verbal-analytical functions and the right hemisphere is responsible for visual-spatial functions (Springer & Deutsch, 1947). The importance of the two hemispheres is that activation of the different hemispheres will be related to the activity that is being performed. For example, when a soccer player is preparing for a corner kick the right hemisphere of their brain will be more aroused than the left hemisphere. This would be opposite for a student competing calculus problems. For the study being conducted, the task of pistol shooting is a visual-spatial task. From the evidence of hemispheric activities, we would expect the right hemisphere of the test subjects to be more aroused.

Those parts of the brain that are in each hemisphere also have individual activities they are responsible for. The frontal lobe is "associated with reasoning, planning, parts of speech, movement, emotions, and problem solving" (Grobstein, 2009). The parietal lobe is "associated with movement, orientation, recognition, [and] perception of stimuli" (Grobstein, 2009). The occipital lobe is "associated with visual processing" (Grobstein, 2009). The temporal lobe is "associated with perception and recognition of auditory stimuli, memory, and speech" (Grobstein, 2009). Figure 5 displays the different areas of the cerebral cortex. When EEG's are taken from the brain they are set up to record readings from the different lobes of the brain. Having this knowledge of brain specificity allows researchers to know when one part of the brain is more aroused than others, which is the case for task specific activities.

Figure 5



Parts of the cerebral cortex. Each area of the brain has a different task they complete in motor activities (Molumby).

Stress, Arousal, and Anxiety

In the study the test subjects perform the shooting task in a competitive environment. Stress, arousal, and anxiety are imposed on athletes during competition and these factors can affect athlete's performance in a negative way if the athlete does not know how to cope with them. Coping with these factors takes experience, practice, and technique. In a study done by Deeny et al. in 2009 it was found that

> a decrease in state anxiety may result in a corresponding decrease in nonessential cortico–cortical communication with the motor cortex, which would then emerge in the form of refined (i.e., more efficient) motor unit activity. Such refinement and simplification in the central nervous system and peripheral musculature would likely result in more accurate and consistent performance. (p.106)

This study is supportive of the individual in the autonomous stage of motor learning. All athletes cope with a competitive environment in different ways. Elite athletes have the ability to cope with the stress the environment is posing on them which will result in less networking and arousal of the brain during the motor performance. This however is not the same for novice athletes. These athletes have to focus harder on the task in order to be successful. This would result in an increase in cortical arousal and increased effort put into the task.

Performing Alone versus Performing in Competition

When performing in competition an athlete needs to know how to cope with all of the environmental factors. Those athletes competing have circumstances happening around them that require the athlete to focus on only what is important to the task at hand. The literature on athletes during competition is centered on the tasks that elite athlete undergo to ensure they perform at their optimal performance. Weinberg & Gould (2003) and Gould, Eklund, & Jackson, (1992a,b) have examined the techniques that elite athletes undergo to focus themselves on competing including a higher level of self confidence, thoughts that are more task oriented and positive, better concentration, lower levels of anxiety, and more positive imagery. These techniques elite athletes engage in allow them to perform better when in competition. These coping factors have been proven to be supportive of the elite athlete. They, however, do not support the novice athlete. The study being done is determining the factors that make individuals in the cognitive stage of motor learning successful at a motor task.

Coherence and "Noise" in The Brain

When performing a sport or activity it is important to be focused to ensure that you do the best you can. The literature on "noise" in the brain focuses on novice athletes having more cortical activation during a performance when compared to the brain of an elite athlete.

Literature that supports the concept that elite athletes have less activity in their brain when competing was done by Babiloni et al, (2008) recording the EEG's of novice and elite gymnasts as they examined videos of gymnasts performing various rhythmic gymnastic moves. The findings of the experiment "showed that low- (about 8–10 Hz) and high-frequency (about 10–12 Hz) alpha ERD in occipital and temporal cortex (ventral pathway) and in dorsal pathway were lower in amplitude in the elite rhythmic gymnasts compared to the non-gymnasts…with respect to the non-athletes, the athletes showed a spatially selective cortical activation (neural efficiency) (p. 519)." This study supports the notion that individuals in the cognitive stage of motor learning have more cortical activation with increased effort to be successful in this stage.

Strengths, Limitations, and Implications of the Literature

The literature to support the study is rich with numerous different studies that all provide background and a foundation to the study that is being conducted for this research. The limitations of the research are that the majority of the information on the subject of alpha band waves in relation to motor skill level is all focused on the individual who is in the autonomous level of motor learning. The expected results of the experiment are going to contradict that of the individual portraying automaticity but the literature now does not support the individual in the cognitive stage of motor learning. The implications of the literature affect the study such that the delimitations of the literature are framing the research questions that are being studied. Since the literature does not explore sufficient material and results with individuals in the cognitive stage of learning the study has been designed to fill in those gaps of the literature.

Research Design and Methodology

Participants

The experiment contained 16 male subjects recruited from ROTC training program at the University of Maryland. All participants are right hand dominant and ipsilateral-eye dominant. Participants were between the ages of 19 and 30, with a mean age of 22.31. All participants were screened with a health history questionnaire to ensure that they were free of neurological and psychiatric disorders and psychotropic medications. Prior to testing, all participants provided written informed consent and they were free to withdraw from the study at any time. The procedure was approved by University of Maryland Institutional Review Board.

Instrumentation

All participants were asked to complete a shooting task under a competitive environment. During practice sessions, participants used their right (dominant) hand to shoot a dry-fire pistol and an optical shooting simulator. Participants assumed a standard shooting posture; feet were positioned approximately shoulder-width apart and nearly perpendicular to the shooting lane to minimize sway. Participants extended the shooting arm while aiming and sighted the target with their right eye; the left eye was occluded by a patch over the shooting glasses. Feedback was provided on all trails (shots) in the form of a shooting score and a "clock face" reference to identify the position of the shot on the target.

Physiological Record

Scalp electroencephalographic data was collected using tin electrodes housed within a stretchable lycra cap, (Electro-Cap International, Inc.). Data was acquired from 30 unipolar sites, labeled in accordance with the 10-20 international system (Jasper, 1958). At all sites of interest (Fz, F3, F4, C3, C4, P3, P4, T3, T4, O1, O2), impedances were maintained below 10 kΩ, signal was referenced to linked earlobes and a common ground. All channels were amplified 500 times using Neuroscan Synamps 1, linked to Neuroscan 4.3.3 acquisition/edit software on a Gateway Pentium computer running Windows XP operating system. Bandpass filters were set at .01-100 Hz with a sampling rate of 1,000 Hertz. Electrodes were placed above and below the left eye over the Orbicularis oculi muscle to record eyeblinks. An electronic pulse was sent into the EEG by the shooting simulator to mark onset of the trigger pull into the continuous EEG recording.

Procedures

Participants were asked to refrain from consuming any alcoholic or caffeinated beverages on the day of testing and asked to get 7-8 hours of sleep the prior night. Participants were prepared for electrocortical (EEG) monitoring. Participants were allowed 10 sighting shots prior to each testing session. Feedback was provided in the form of their score and a "clock face" reference to indicate shot placement. The subjects then executed the 40 test shots for the session. The competitive test shooting trials included shooting against another study participant.

During the competition, participants took turns shooting and alternated between shooting order such that in one trial, shooter A shot first followed by shooter B, but the next trial shooter B shot first, etc. Participants were instructed to set the gun down between each shot and to remain standing throughout the shooting session. After each trial, scores were presented to the competitors and a winner of that trial was declared. During competition the following psychological pressures - in addition to peer-competition - were imposed on the subjects:1) social evaluation by a superior officer who conspicuously took notes and evaluated participants' shooting stance and accuracy; 2) financial loss or gain of 50 cents per round, from a starting sum of $20 (in the case of equal scores, the sum at stake carried over to the next shot) , a dollar bonus for a bull's-eye and a dollar loss for missing the target completely; 3) a 30 second time constraint for each shot, beginning when the subject grasped the pistol; 4) video camera recording; and 5) participants were placed on teams such that their score contributed to overall team score, both of which were displayed outside the ROTC field house. Participants were informed of all of these pressures during the instructional period prior to task execution and were told to attempt to "beat" their competitors' score.

Signal Processing

Hypothesis I: Power. Spectral analysis was calculated in Neuroscan using preprocessed data. Power was computed in Neuroscan for each epoch using a

Hamming window with a 50% overlap. The 1 Hz bins were then averaged to obtain power estimates for the frequency bands of interest: Low Alpha 8-10Hz. These estimates were then log transformed to ensure a normal distribution.

Hypothesis II: Coherence. Amplitude coherence calculated in Neuroscan using preprocessed data. This was done using traditional 5 homologous pairs to electrode Fz. The 1 Hz bins were then averaged to obtain coherence values for the frequency bands of interest: High Alpha 10-13Hz. Values were fisher-z transformed in order to approximate normality prior to statistical analyses.

Statistical Design

The statistical design for the experiment was regressing motor performance variables (variability and jerk) on different cortical processes (arousal and networking to the motor planning region). These regressions were then used to determine the results of the study.

Strategies for Minimizing Bias and Error

The following methods were used to reduce bias and error. In order to reduce the influence of eye blinks on the EEG data an ocular artifact reduction filter was applied (Semlitsch, 1986). The 4-s period of continuous data prior to the completion of each shot was then partitioned into four successive 1-s epochs. The termination of the final epoch was coincident with the trigger pull (i.e., the numbering of epochs was based on a temporal sequence during the aiming period so that Epoch 4 represented the initial 1-s period preceding sequentially Epoch 3, Epoch 2, Epoch 1, and the shot). The data were then baseline corrected and linear detrended. A final visual inspection of all sweeps was performed to remove any epochs that still contained artifact.

Ethical Considerations

In the experiment performed humans were used to perform the test shots. The test subjects were shown no harm and were safe at all times. The pistols used in the experiment did not contain real bullets and were therefore not a safety hazard. All subjects gave their informed consent before participating in the experiment.

Role of Researcher

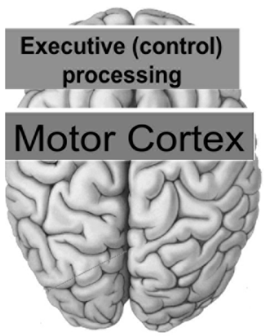
The role of the researcher was to analyze the alpha band waves of the EEG of the 16 test subjects for one second before the pistol was shoot. The researcher did not actually perform the experiment with the pistol shooters as they went through the performance alone, intervention, and competition phases. The researcher took the datum from the EEG readings from the subjects during the competition phase to analyze for the purpose of this study.

Results, Conclusions, and Recommendations for Future Research

Results

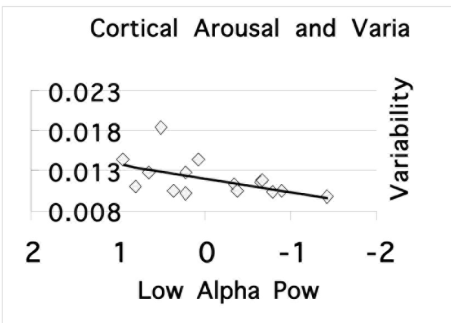
When analyzing the results of the study, there are very distinct results. The EEG brain waves of high alpha coherence and low alpha power were evaluated from all 16 test subjects. The first hypothesis stated was: higher cortical arousal (i.e. lower alpha power), will be associated with better performance (i.e., less variable pistol trajectories). This hypothesis has been proven true. Those individuals that had more engaged/aroused brains performed better. The more aroused the test subject was the less variable the shot was. Specifically, more cortical arousal at the control part of the brain and the motor centers of the brain were associated with less variable shot trajectories. ($p < .05$). See figure 6 and graph 1.

Figure 6



The motor cortex and control center of the brain are the areas that have the highest cortical arousal during the pistol shooting resulting in less variability.

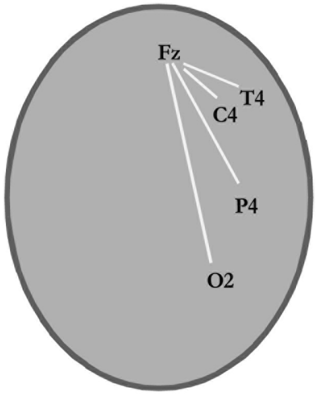
Graph 1



As the low alpha power decreases (i.e. cortical arousal increases) the variability of the shot decreases as well.

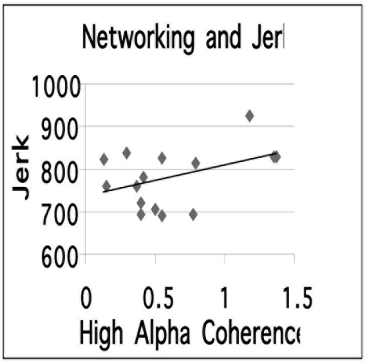
The second hypotheses to prove was networking to the motor planning region (i.e. higher coherence) will be positively associated with increased levels of jerk. It has been found that those individuals that had more communication to the motor planning part of the brain performed better. Specifically, more networking from the visual-spatial brain areas (right hemisphere) were associated with an increased ability to stay on the target. ($p < .05$). See figure 7 and graph 2.

Figure 7 Visual-spatial side: Right hemisphere



Networking is high in the areas of the brain in the right hemisphere. The task is a visual-spatial task which makes the right hemisphere network more during the cognitive stage of motor learning.

Graph 2



As the high alpha coherence increases the jerk of the pistol shot increases as well. The higher the jerk of the shot is the better the shot is.

Conclusion

As stated above in chapter one, the lower component of alpha waves (8-10hz) is characterized to be representative to changes in the overall arousal of the brain. The higher component of alpha waves (10-13hz) is characterized by representing task-specific arousal and/or "relaxation" (Klimesch, 1999 and Smith et al., 1999 in Deeny, Hillman, Janelle, and Hatfield 2003). The alpha power represents cortical activation for the specific task of shooting the pistol at the target. As high alpha coherence increased in the right hemisphere the jerk of the shot increased also. The increase in jerk is a positive action due to the fact the test subject was actively engaged in the task. The increased jerk shows that the test subject was rigorously trying to keep the shot on the target. This exerted effort to hold the pistol shot on the target before shooting results in more rapid movement, hence a higher jerk in the performance.

The results also found that when low alpha power is low the variability of the shot is low as well. The decrease in low alpha power shows that the cortical activity had increased in the brain. The increase in cortical activity is due to the individual in the cognitive stage of learning being aroused and engaged in the pistol shooting activity. As the test subjects are performing the shooting experiment they are thinking about all of the steps that they have to take in order to make a successful shot. The test subjects are also paying attention to the external cues, environment, and the stakes that have been put forth for the competition. All of these factors affect the performance of the novice athlete. These same factors would not play as big of a role in the elite athletes and therefore would not affect them as significantly since they are in the autonomous stage of learning.

This study supports Fitts and Posner's model of successful performance during the early stage of motor learning. Specifically, these brain processes were: increased activation of task relevant brain areas and networking to the motor planning region of the brain from visual-spatial brain areas. Those who performed better (less variability and more jerk) exhibited brain patterns associated with relying on external cues, events and responses. That is, active, engaged, and highly networked brain processes were associated with superior motor performance at this early stage of learning.

Recommendations for Future Research

Future research can be done to expand on this study. In this study, only the alpha band waves of the test subjects were evaluated. Although only these waves were interpreted, there are other brain waves that show changes and are significant during a task in a competitive environment like beta, gamma, and theta. It is important to evaluate the different brain waves because each brain wave can give different insight into how areas of the brain are affected by stressors in the cognitive stage of motor learning since each frequency wave represents a particular action. For example, the beta brain waves are representative of alertness, concentration and cognition (Howell, 2009).

Another recommendation for future research is that related to the stages of motor learning proposed by Fitts and Posner that were so deeply studied in the previous study. There is ample amount of supporting evidence for the individual in the autonomous stage of motor learning. This study here has found evidence to support the notion of a successful individual in the cognitive stage of learning. A future study can be done to find evidence to support the middle stage of the motor learning stages. The individual in the associative stage executes motor tasks a specific way to be successful. Doing an experiment to test the proposal done by Fitts and Posner will add more evidence and insight into the individual during this stage of motor learning. Having all three stages examined and studied provides more support for the motor learning stages.

Bibliography

Babiloni, C., Del Percio, C., Rossini, P. M., Marzano, N., Iacoboni, M., Infarinato, F., Lizio, R., Piazza, M., Pirritano, M., Berlutti, G., Cibelli, G., Eusebi, F. (2008). Judgment of actions in experts: A high-resolution EEG study in elite athletes. ScienceDirect. *Elsevier Journal. NeuroImage 45*, 512-521. Retrieved June 6, 2009

Baumeister, R. F. (1984). Choking under pressure: self-consciousness and paradoxical effects of incentives on skilful performance. . *Journal of Personality and Social Psychology*, *46*, 610-620. Retrieved June 9, 2009

Centre for Geriatric Care (2008). Brain Noise Is Good: New Study Overturns Notion That Brain Noise Quiets Down With, (n.d.). *Science Daily: News & Articles in Science, Health, Environment & Technology*. Retrieved July 10, 2009, from http://www.sciencedaily.com/

Deeny, S. P., Hillman, C. H., Janelle, C. M., & Hatfield, B. D. (2003). Cortico-cortical Communication and Superior Performance in Skilled Marksmen: An EEG Coherence Analysis. *Journal of Sports & Exercise Psychology*, *25*, 188-204. Retrieved June 10, 2009

Deeny, S. P., Haufler, A. J., Saffer, M., & Hatfield, B. D. (2009). Electroencephalographic Coherence During Visuomotor Performance: A Comparison of Cortico–Cortical Communication in Experts and Novices. *Journal of Motor Behavior* , *41*(*2*), 106-116. Retrieved June 2, 2009

Del Percio, C., Babiloni, C., Comani, S., Eusebi, F., Bertollo, M., Marzano, N., Iacoboni, M., Infarinto, F., Lizio, R., Stocchi, M., Robazza, C., & Cibelli, G. (2009). Visuo-Attentional and Sensorimotor Alpha Rhythms are Related to Visuo-Motor Performance in Athletes. *Human Brain Mapping*, Retrieved June 4, 2009

Fitts, P. M., & Posner, M. I. (1967). *Human Performance*. Belmont, CA: Brooks/Cole.

Gould, D., Eklund, R., & Jackson, S. (1992a). Coping strategies used by more versus less successful Olympic wrestlers. *Research Quarterly for Exercise and Sport*, *64*, 83-93. Retrieved June 11, 2009

Gould, D., Eklund, R., & Jackson, S. (1992b). 1988 US Olympic wrestling excellence I: Mental preparation, precompetitive cognition, and affect. *Sport Psychologist*, *6*, 358-382. Retrieved June 11, 2009

Grobstein, P. (2009). *Brain Structures and their Functions* . Retrieved June 10, 2009, from serendip.brynmawr.edu/bb/kinser/Structure1.html

Hatfield, B. D., & Hillman, C. H. (2001). *The psychophysiology of sport: A mechanistic understanding of the psychology of superior performance*. New York: Wiley.

Haufler, A. J., Spalding, T. W., Santa Maria, D. L., & Hatfield, B.D. (2000). Neuro-cognitive activity during a self-paced visuospatial task: Comparative EEG profiles in marksmen and novice shooters. *Biological Psychology, 53,* 131–160. In Deeny, S. P., Haufler, A. J., Saffer, M., & Hatfield, B. D. (2009). Retrieved June 2, 2009

Haufler, A. J., Spalding, T. W., Santa Maria, D. L., & Hatfield, B.D. (2002). Erratum to "Neuro-cognitive activity during a selfpaced visuospatial task: Comparative EEG profiles in marksmen and novice shooters." *Biological Psychology, 59,* 87–88. In Deeny, S. P., Haufler, A. J., Saffer, M., & Hatfield, B. D. (2009). Retrieved June 2, 2009

Howell, K. (2009). *Brainwave States: Beta*. Retrieved July 10, 2009, from http://www.brainsync.com/brainlab_beta.asp

Jasper, H. (1957). Report of the Committee on Methods of Clinical Examination in Electroencephalography. . *Electroencephalogr Clin Neurophysiol.*, *10*, 371-375. Retrieved July 9, 2009

Jausˇovec, N. (2000) Differences in cognitive processes between gifted, intelligent, creative, and average individuals while solving complex problems: an EEG study, *Intelligence*, 28, 213–37. Staudt, B., & Neubauer, A. C. (2006). Retrieved June 12, 2009

Kerick, S. E., Douglass, L. W., & Hatfield, B. D. (2004). Cerebral cortical adaptations associated with visuomotor practice. *Medicine and Science in Sports and Exercise, 36,* 118–129. In Deeny, S. P., Haufler, A. J., Saffer, M., & Hatfield, B. D. (2009). Retrieved June 2, 2009

Klimesch, W. (1999). EEG alpha and theta oscillations reflect cognitive and memory performance: A review and analysis. *Brain Research Review*, **29**, 169-195. In Deeny, Hillman, Janelle, & Hatfield (2003). Retrieved June 9, 2009

Maxwell, J., Masters, R., & Eves, F. (2000). From novice to no know-how: A longitudinal study of implicit motor learning. *Journal of Sports Sciences*, *18*, 111-120. Retrieved June 18, 2009

Molumby. (n.d.). *Welcome to UIC*. Retrieved June 5, 2009, from http://images.google.com/imgres?imgurl=http://www.uic.edu/classes/bios/bios100/lecturesf04am/cerebrum_1.gif&imgrefurl=http://www.uic.edu/classes/bios/bios100/lecturesf04am/lect22.htm&usg=__Kzdc6b6EEmqdzwez4YGYoDFas9Q=&h=381&w=464&sz=42&hl=en&start=5&um=1&tbnid=LutJmC5aiMXA7M:&tbnh=105&tbnw=128&prev=/images%3Fq%3Dparts%2

Rhodes, M. (n.d.). *Electroencephalogram (EEG) Test*. Retrieved July 10, 2009, from http://www.webmd.com/epilepsy/electroencephalogram-eeg-21508

Semlitsch, H. V., Anderer, P., Schuster, P., & Presslich, O. (2009). A Solution for Reliable and Valid Reduction of Ocular Artifacts, Applied to the P300 ERP. *Psychophysiology*, *23*(*6*), 695 - 703. Retrieved July 10, 2009, from http://www3.interscience.wiley.com/journal/119492537/

Smart Destinations. (2008). *Miami Golf Kid*. Retrieved June 1, 2009, from http://gomiamicard.com/blog/files/2008/01/miami-golf-kid.jpg

Springer, S. P., & Deutsch, G. (1947). *Left Brain Right Brain: Perspective from Cognitive Neuroscience*. New York: W.H. Freeman And Company.

Staudt, B., & Neubauer, A. C. (2006). Achievement, underachievement and cortical activation: a comparative EEG study of adolescents of average and above-average intelligence . *High Ability Studies*, *17*(*1*), 3-16. Retrieved June 12, 2009

Syamsulariff. (n.d.). *Tiger Woods*. Retrieved June 3, 2009, from www.progolferclub.com/blog/wp-includes/images/tiger_woods.jpg

Weinberg, R., & Gould, D. (2003). Introduction to psychological skills training. In R.S. Weinberg, & D.R. Gould (Eds.), *Foundations of sport and exercise psychology* (3rd ed.). Champaign, IL: Human Kinetics.

Weiss, S., & Mueller, H. M. (2003). The contribution of EEG coherence to the investigation of language. *Brain and Language, 85*, 325-343. Retrieved June 15, 2009