ABSTRACT

Title of Thesis: EXERCISE AND THE AGING BRAIN: A NEUROIMAGING STUDY OF FRONTAL LOBE FUNCTION DURING EXECUTIVE CHALLENGE IN OLDER MEN AND WOMEN WHO VARIED IN PHYSICAL ACTIVITY PARTICIPATION

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Physical activity preserves neurocognitive functioning in older adults by increasing brain blood flow and preserving neurotransmitter activity. Because the frontal lobes show the greatest decline, the most apparent difference was expected between physically inactive versus active individuals when performing tasks that challenge frontal lobes. Adults (66-92 years) with varied physical activity levels were administered binaural auditory oddball and go-nogo tasks. The nogo trials challenged executive processes through response inhibition. Physical activity was indexed with the Yale Physical Activity Survey. EEG was recorded from frontal, central, and parietal sites. Multiple regression analysis revealed that the overall relationship of P300 amplitude to age and physical activity was significant during nogo trials at site F3, F (2, 75) = 3.61, p = .032 and at site FZ, F (2, 75) = 6.26, p = .003. In summary, physical activity is associated with a specific effect on the aging brain revealed during executive challenge.

EXERCISE AND THE AGING BRAIN: A NEUROIMAGING STUDY OF FRONTAL LOBE FUNCTION DURING EXECUTIVE CHALLENGE IN OLDER MEN AND WOMEN WHO VARIED IN PHYSICAL ACTIVITY

by

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DEDICATION

I dedicate this thesis to my father, Thomas Joseph Stover. Although you can not be here to witness the hard work and happiness that went into completing my degree, I know you are always with me. Your encouragement to enter the realm of Sport Psychology led me to more than I ever hoped for. There is not a day that goes by that I don't stop and think of you. Your love and support are what carried me through and helped me to believe in myself.

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To my family, thank you for supporting me throughout my education. Your love enabled me to keep my head up during trying times.

To my husband Michael, thank you for your smiles and words of kindness. Your love and support helped me to keep going and not give up along the way.

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CHAPTER I

INTRODUCTION

As we age, our physical and mental abilities change considerably. Similarly, central nervous system functioning also changes as we get older. The body and brain mature rapidly during the early years of life, enabling us to gain mastery of our surroundings. As we mature into the second decade, most physical and central nervous systems are matured, and maintained for a short time (Roberts, 1972). Starting in the 40's, and continuing during the remainder of life, a gradual deterioration of behavioral and biological functioning occurs within the brain and body. There is much variability however, in the loss of functionality that occurs with aging. Many are able to maintain their physical and mental prowess, while others struggle to think clearly and perform daily activities. Recent investigations have suggested that physical activity may benefit not only our physical bodies, but our mental functioning as well. A case has been made for the slowing of the cognitive aging process through physical activity. The following study will examine the relationship of cognitive function in an elderly population with physical activity from a neurobiological perspective.

It is estimated that by 2025 25% of Americans will be over the age of 65. It is also predicted that in 2025, over eight million Americans will be 85 years of age or older (U.S. Census Bureau, 1990). Cognitive function and emotional well-being are imperative to the quality of life in older adults. Unfortunately, dementia and depressive disorders are prevalent in this population. One factor that has been demonstrated empirically to influence the decline of neural processes during aging in a positive manner is physical activity.

Researchers agree that there are many physical and emotional benefits of physical activity. A brisk walk or a swim can improve sleep (Brassington & Hicks, 1995) and help regulate blood glucose levels (Giacca, Shi, Marliss, Zinman, & Vranic, 1994). Long-term participation can improve cardiovascular functioning, increase muscle strength, and enhance balance and flexibility (WHO, 1997; ACSM, 1999). The physiological benefits of physical activity apply equally to almost all persons regardless of their age. In addition, a number of remarkable psychological benefits accrue from a lifestyle of physical activity for those who are able to participate. Psychological benefits of physical activity include improved mood state (Landers & Petruzzello, 1994; Nieman, Warren, Dotson, Butterworth, & Henson, 1993) and relaxation. Physical activity can also help older persons adjust to the social pressures of aging. Due to factors such as death of friends and loved ones, financial hardship, retirement, and ill health, many older persons have difficulty adjusting to old age (McPherson, 1990). Enhanced life satisfaction, increased self-confidence, and better cognitive functioning (Berger & Hecht, 1990; McAuley & Rudolph, 1995; O'Connor, Aenchbacher, & Dishman, 1993) are some of the long-term benefits of a life of physical activity.

In the process of normal aging, the human brain begins to lose tissue early in the third decade of life. It is estimated that 15% of the cerebral cortex and 25% of cerebral white matter is lost between ages 30 and 90 (Colcombe et al., 2003). Given the projected rapid growth in the aged population in developed countries (Tang, Antolin, & Oxley, 2001), and the staggering costs associated with cognitive deterioration, identifying interventions to protect against structural and functional declines of the central nervous system is rapidly emerging as an imperative public health goal. Cognitive decline is most evident for those processes mediated by the frontal lobes of the brain (Dempster, 1992; Haug & Eggers, 1991; West, 1996).

Early research into the relationship between age and physical activity relative to cognitive performance focused on simple and choice reaction time. Spirduso (1975) showed that older active men reacted faster and performed similarly to younger active men than their less active counterparts or young non-active men. It was concluded that aerobic fitness is associated with improved performance on cognitive functioning and psychomotor speed (Spirduso, 1980). Additional studies have found age-related differences in performance on some cognitive tasks are attenuated in participants with high- compared to low-physical exercise (Dustman et al., 1984; Spirduso, 1980; Baylor & Spirduso, 1988), although strong effects are not always obtained (cf. Blumenthal & Madden, 1988; Dustman, Emmerson, & Shearer, 1994). Older persons who are aerobically fit have demonstrated superior ability in attention, processing speed, short-term and effortful memory, fluid intelligence, and perceptual set shifting (Bashore & Goddard, 1993; Chodzko-Zajko, Schuler, Solomon, Heinl, & Ellis, 1992; Christensen & Mackinnon, 1993; Dustman et al., 1984; Etnier, Landers, Petruzzello, Han, & Nowell, 1997; Hassmen, Ceci, & Backman, 1992; Kramer et al., 1999; Landers & Arent, 2001; Powell & Pohndorf, 1971). Kramer et al. (1999) found evidence to support the notion regarding the specificity of exercise and executive processes while measuring several executive functions before and after six months of either an aerobic walking program or anaerobic toning and stretching program. Participants in the aerobic group showed greater improvement than the anaerobic group on task switching, stopping, which measures the ability to abort a preprogrammed action, and response compatibility, which measures the ability to ignore stimuli irrelevant to the task. Additionally, there were no differences between groups for the reaction time on non-switch trials but this difference from the other cognitive measures was expected since non-switch reaction time does not depend on executive control functions. Furthermore, selective benefits were not found for spatial attention, visual search, digit-digit and digit-symbol comparison tasks, all of which do not rely on frontally mediated executive processes (Kramer et al., 1999).

Recent examinations of the link between cardiovascular exercise and CNS health that used animal models have shown positive effects of aerobic fitness on a wide range of brain health markers. These effects are exerted by a chain of cellular and molecular cascades including increased levels of brain-derived neurotrophic factor, serotonin, capillary density (Cotman & Berchtold, 2002), and neurogenesis (van Praag, Kempermann, & Gage, 1999). These changes result in a well-preserved brain that is more plastic and adaptive to change. It has been shown that physical activity also has beneficial effects on the human brain, reversing the aging process in these areas by preserving blood flow and neurotransmitters (Spirduso, 1980; Chodzko-Zajko & Moore, 1994; West, 1996; Colcombe & Kramer, 2003). Upregulation of brain-derived neurotrophic factor (nutrition for the brain) is increased in individuals who are physically active, leading to the promotion of neurogenesis, and improvements in learning (Cotman

& Berchtold, 2002). This effect extends into the frontal lobe of the brain (C.W. Cotman, 2003, personal communication, June 3, 2003). Because the frontal area ages fastest, the differences between fit and unfit elderly individuals may be most apparent for frontally mediated cognitive processes.

One of the ways to record basic cognitive processing is to measure the brain's activity. Electroencephalography is the measurement of cerebral cortical activation. This tool can be useful for understanding cortical topographical activity in response to a behavioral challenge. Averaging the cortical responses to such behavioral challenges over a number of trials can result in the discernment of event-related potentials (ERPs) that contain a number of components. These components index various neural processes involving sensory (i.e., exogenous) and cognitive (i.e., endogenous) events. The P300 is an "endogenous" rather than an "exogenous" component because it is independent from the stimulus evoking it and is associated with cognition. Of the endogenous event-related potential components, the P300 appears to be one of the most robust (Ortiz, Loeches, Miguel, Abdad, & Puente, 1994). The P300 waveform is a positive deflection in the resulting time series that occurs at least 300 ms beyond stimulus presentation that can be characterized by both amplitude and latency. Amplitude is defined as the voltage difference between a prestimulus baseline and the largest positive-going peak of the ERP waveform within a latency range (e.g., 300-650 ms). According to Polich (1996) P300 amplitude is related to the neural resources allocated in decision-making or stimulus recognition and typically decreases with age. P300 latency (ms) is defined as the time from stimulus onset to the point of maximum positive amplitude within the latency window and provides an index of the time involved to process the stimulus. (Polich, 1996). Latency of the P300 is increased in older adults, indicating a delay in cognitive processing (Brown, Marsh, & LaRue, 1983). ERPs can be recorded during varying types of cognitive challenge. One basic distinction in this regard is the classification of executive and non-executive type cognitive processes. Executive processes require high levels of attention and are susceptible to degradation with increasing age. Executive processes are effortful processes involved with the selection, inhibition, scheduling and coordination of the computational processes that are responsible for perception, memory, and action (Kramer et al., 1999). Non-executive tasks rely on processes that are not dependent on the frontal lobe but depend instead on other areas of the brain. Such automatic processes depend on component task processes that are mostly perceptual and action related (Kramer et al., 1999). The former can be assessed in a basic manner with ERPs via a response inhibition task, the go-nogo, which elicits a P300 during the nogo trials. In this protocol the amplitude and latency of the P300 component of the resulting ERP indicates the integrity of cortical response to a basic executive challenge.

Research has supported that executive function is mediated by the frontal lobes. Weisbrod, Kiefer, Marzinzik, and Spitzer (1999) noted that schizophrenic patients suffer from severe deficits in executive function, likely due to degenerative processes in the frontal lobes. In this regard Roth, Horvath, Pfefferbaum, and Kopell (1980) reported that schizophrenics also displayed decreased amplitude of frontal P300 when compared with controls during an executive task paradigm. This decrement was particularly pronounced in the left frontal area. Older men and women are also known to suffer from degeneration of the frontal lobes. Blood flow, brain weight, and cortical thickness show remarkable signs of decrease in this region (Dempster, 1992). Functionally, such older individuals show significant executive deficits. Therefore, older men and women are also likely to reveal reduced left frontal P300 amplitude during basic executive challenges when compared to younger individuals. However, exercise participation has clearly been shown to attenuate the deficit in frontally mediated (i.e., executive) cognitive function in older men and women (Kramer et al., 1999). Logically, it can be deduced from the studies above that exercise participation should reduce left frontal (F3) deficit in the elderly, also resulting in heightened P300 amplitudes in those who are more physically active.

Therefore, in light of the beneficial effects of exercise on the frontal lobe it would seem that the P300 elicited at F3 during a response inhibition task would be positively associated with physical activity in a group of older individuals. The purpose of the present study is to examine the relationship of the frontal P300 amplitude to physical activity history in older men and women.

Statement of Problem

From the previous investigations, most research to date on the effects of the aging brain on the P300 have not considered the role of physical activity as a mediating influence on the age-related change. Physical activity is a major contributor to maintaining a healthy lifestyle into old age because it appears to preserve brain structures related to cognitive function. Cognitive tasks requiring response inhibition are affected by physical activity in a positive manner (Kramer et al., 2001), whereas tasks requiring little such effort are not affected by physical fitness. Aerobic exercise specifically targets areas of the brain where executive control functions are processed, leading to improvements on tasks related to executive control. However, no research has been reported to date in which activation of the frontal lobes has been assessed during the performance of such tasks in older individuals who vary in their participation in physical activity. As such, a number of investigators have examined the specific effects of exercise on cognitive function (Kramer et al., 1999) and on brain processes in animals (Cotman & Berchtold, 2002), but the relationship between exercise and neurobiological function in the human brain is still in need of further study.

A positive relationship is predicted between physical activity and cognitive function but it appears reasonable that the greatest benefits would be in the frontal region of the brain, which mediates executive processes such as response inhibition. The purpose of the present study was to determine if superior frontal lobe function during executive challenges is associated with a more physically active lifestyle in older individuals relative to those who are sedentary.

Hypotheses

Hypothesis 1:

A positive relationship is predicted between P300 amplitude at the left frontal (F3) site and physical activity level during the nogo trials of the go-nogo task.

Hypothesis 2:

A negative relationship (i.e., negative slope) is predicted between P300 latency and physical activity level for left frontal (F3) in the nogo trials of the go-nogo task.

Note 1:

No such relationships, as outlined in hypotheses 1 and 2, were predicted for P300 amplitude and latency at site F3 during the rare or target trials of the oddball task.

Note 2:

In an exploratory manner, the same regression analyses as specified for amplitude and latency at site F3 will be conducted on all remaining sites to determine the relationship between global topographical cortical responses and physical activity level during the rare or target trials of both the go-nogo and oddball tasks. In general, it was expected that any such relationships would be stronger during the target trials of the go-nogo task relative to the oddball task.

Definition of Terms

1. P300: an endogenous component of a stimulus evoked event-related potential in the brain which occurs at approximately 300 ms that provides an index of basic cognitive function.

2. Response Inhibition: The ability to inhibit a response to a particular stimulus requiring cognitive effort.

3. Physical Activity: Any type of voluntary bodily movement that is produced by skeletal muscles.

4. Exercise: Activity that requires physical or mental exertion, especially when performed to develop or maintain fitness.

5. Fitness: The measure of how well an individual is adapted to a specific work demand. This adaptation results is heightened capacity to perform maximal work and in greater efficiency (i.e., reduced strain) during the performance of sub-maximal work.

Delimitations

1. The participant population were primarily healthy adults 66 years of age and older. (Ages ranged from 66-92 with the average age of 79.1)

2. The participant population was high functioning independent living educated adults (55 female, 23 male).

Limitations

1. This study was cross-sectional in nature, therefore only relationships may be demonstrated, not causation.

CHAPTER II

REVIEW OF LITERATURE

The following review will examine the literature in a variety of areas associated with age, physical activity, and cognition. Changes in brain structure and function related to aging will be identified. Event-related potentials will be discussed relating to cognitive function and age. Specifically, the P300 event-related potential will be discussed. Next, the relationship between central nervous system functioning and physical activity will be considered. The research will then be expanded to cover the relationship between physical activity, aging, and cognitive function. Specifically, the effect of physical activity in an aging population on the P300 event-related potential will be discussed.

The Aging Brain

Decrements in brain weight and cortical thickness in midfrontal, superior temporal, and other cortical association areas have been observed in aging (Coffey et al., 1992; Jernigan et al., 1991; Terry, DeTeresa, & Hansen, 1987). Histological examinations indicate age-related changes in higher-order association cortices that are thought to occur as a consequence of cell loss (Brizzee, 1981; Brody, 1973; Henderson, Tomlinson, & Gibson, 1980; Kemper, 1984; Scheibel & Scheibel, 1975) and/or shrinkage of large neurons (Terry, DeTeresa, & Hansen, 1987). Reduced density of neuronal spines and synaptic connections (Feldman, 1976; Katzman &Terry, 1983; Mervis, 1978; Scheibel, 1979) and the loss of horizontal dendrites (Scheibel & Scheibel, 1975) result in a loss of complex programming functions within the brain and an impairment of extra- and intracortical communication. Also, degradation of neurotransmitter activity is believed to be an important element that contributes to neural degeneration and age-related changes in behavior (Carlsson, 1987; Petkov, V.D, Petkov, V.V. & Stanciieva, 1988). These changes are most pronounced in the frontal area of the brain. Dempster (1992) reported that the frontal lobes are one of the first areas in the brain to show signs of deterioration with age and that blood flow, brain weight, and cortical thickness decreases in this region. Kramer and colleagues (1999) observed age-related decreases in the performance of executive tasks mediated by the frontal lobes. These executive processes involve planning, scheduling, response inhibition, working memory, suggesting that frontal lobe decline is responsible for these decrements. A basic task such as a go-nogo paradigm tests response inhibition- or the stoppage of a response to a particular task. Older individuals would be expected to perform poorly relative to younger individuals. Such a task elicits an event-related potential that can be examined to assess cortical inhibitory ability. Specifically, the P300 component of this event-related potential yields both latency and amplitude measures. Older individuals tend to have longer latencies and decreased amplitudes than younger individuals.

In regard to frontal lobe decline, schizophrenics can serve as a model of extreme aging. Weisbrod, Kiefer, Marzinzik, and Spitzer (1999) noted that schizophrenic patients suffer from severe cognitive and attentional deficits, particularly from failure of executive control functions. Roth, Horvath, Pfefferbaum, and Kopell (1980) reported that schizophrenics displayed decreased amplitude of frontal P300 when compared with controls on an executive task paradigm. This decrement was particularly pronounced in the left frontal area. The P300 component of the event-related potential elicited by a basic attention task is a basic quantitative index of cognitive function. When challenged with a task not involving response inhibition (i.e. executive control), schizophrenics performed similarly to controls (Weisbrod, Kiefer, Marzinzik, & Spitzer, 1999). As such, event-related potentials were sensitive to the neurophysiological substrate of this dysfunction. Frontal amplitude was decreased in schizophrenics indicating that their brain activity is not as vigorous as normal patients. Although not characterized by such severe frontal decline, frontal amplitude of the P300 is also decreased in older individuals. In this manner, brain responses in older adults are directionally similar to those of schizophrenic patients, indicating a decline in frontal lobe function.

Alzheimer's disease is another brain disorder that occurs in older persons. In a study by Frodl et al. (2002) P300 amplitudes were significantly diminished and latencies were significantly prolonged in patients with Alzheimer's disease suggesting that P300 amplitudes and latencies may be an accurate, inexpensive, noninvasive, clinically available marker for Alzheimer's disease. Event-related potentials may provide future insight to many pathways in the brain.

The P300 Component of the Event-Related Potential

The P300, or P3, is a component of the event-related potential evoked by a detected improbable signal which contains a late positive component. (Sutton, Braren, Zubin, & John, 1965; Squires, Squires, & Hillyard, 1975; Simson, Vaughan, & Ritter, 1977; Ritter, Simson, Vaughan, & Friedman, 1979; Naatanen, Simpson, & Loveless, 1982). An event-related potential (ERP) reflects a time series of fluctuating voltages recorded from the scalp surface in response to a target stimulus. Topographically, the P300 component is represented by a parietal maximum. The P300 component of the ERP has demonstrated considerable utility in the study of aging because it is thought to result from neural activity associated with memory and attentional processes. This positive peak occurs about 300 ms after a specific event in young adults. Picton, Stuss, Champagne, and Nelson (1984) found that the P300 component of the event-related potential shows consistent and significant age-related changes because of changes in human cerebral function. It has also been used to evaluate mental function in patients with neurological and psychiatric disorders (Brown, Marsh, & LaRue, 1982; Goodin, Squires, Henderson, & Starr, 1978a; Hansch et al., 1982; Pfefferbaum, Ford, Wenegrat, Roth, & Kopell, 1984b; Squires, Chippendale, Wrege, Goodin, & Starr, 1980). In a study investigating Alzheimer's disease, Ortiz, Loeches, Miguel, Abdad, and Puente (1994) found the P300 useful for diagnosing dementia. P300 latency and amplitude were measured in normal and demented individuals. Significant differences between control and dementia groups were noted in the P300 latency, but not amplitude in the left temporal and parietal areas of the brain. The above findings suggest that the P300 may be a robust neurophysiological marker in dementia.

The simplest way to record this component requires that the participant attend to a series of regularly occurring stimuli in order to detect occasional targets that differ from the standard stimuli by some simple physical characteristic. This has often been called the "oddball" paradigm (Picton, Stuss, Champagne, & Nelson, 1984). The P300 is measured by quantifying its amplitude (size) from baseline and latency (timing) from stimulus presentation. Amplitude is defined as the voltage difference between a prestimulus baseline and the largest positive-going peak of the ERP waveform within a latency range (e.g., 300-650 ms, although the range can vary depending on participant characteristics, stimulus modality, task conditions, etc.). Latency (ms) is defined as the time from stimulus onset to the point of maximum positive amplitude within the latency window (with 300 ms being the modal latency when the component is elicited by using auditory stimuli in young adults- hence the name). In addition, P300 scalp distribution is defined as the change in component amplitude across the midline recording sites from the Fz (frontal), Cz (central), and Pz (parietal) locations. Scalp distribution effects are of substantial importance because variation in amplitude from the manipulation of task or subject variables has been used to infer information about P300 neural generators (Johnson, 1993). The usual interpretation of P300 latency is that it is a metric of stimulus classification speed (Kutas, McCarthy, & Donchin, 1977; Magliero, Bashore, Coles, & Donchin, 1984; Polich, 1986c, 1987a), is generally unrelated to response selection processes (Duncan-Johnson & Donchin, 1982; McCarthy & Donchin, 1981; Pfefferbaum, Christensen, Ford, & Kopell, 1986; Ritter, Simson, Vaughan, & Macht, 1983), and is, therefore, independent of behavioral response time (Duncan-Johnson, 1981; Novak, Ritter, Vaughan, & Wiznitzer, 1990). Indeed, it is these very properties that make the P300 a valuable tool for the assessment of cognitive aging.

At least two factors go into the determination of P300 amplitude. One is the amount of information received by the participant, which is a function of the a priori uncertainty of the event's occurrence minus an information loss due to the a posteriori uncertainty of having correctly perceived the event (Ruchkin & Sutton, 1977). A second factor determining P300 amplitude is attention, a factor that also operates on some level to affect the amount of information the participant receives. Instructions that induce the participant to allocate more attention to the stimuli increase P300 amplitude (e.g., Squires, N.K., Squires, K.C, & Hillyard, 1975; Squires, K.C., Donchin, Herning, & McCarthy, 1977).

The P300 component has been related to many aspects of human information processing. It is called an "endogenous" rather than an "exogenous" component because it is independent from the stimulus evoking it. The P300 increases in amplitude when the target becomes more improbable and therefore more informative (Duncan-Johnson & Donchin, 1977; Campbell, Courchesne, Picton, & Squires, K.C.; Fitzgerald & Picton, 1983). Bashore, Osman, and Heffley (1989) concluded from their meta-analysis of 28 studies that the P300 was delayed by some specific stage of processing rather than the complexity of the task. In addition, the P300 has been related to cognitive processes that occur after incoming information has been analyzed. Donchin (1981) hypothesized that the P300 component represents the updating of memory once sensory information has been analyzed. According to Polich (1996), P300 amplitude indexes attentional resource allocation when memory updating is engaged; P300 latency indexes the time taken to allocate resources and engage memory updating.

These theoretical views of P300's neuropsychological meaning will serve as a basis for how this ERP component measures the cognitive changes brought on by normal aging.

P300 and age

Event-related potentials provide a somewhat different approach for studies of CNS functioning compared to cognitive assessments as they yield a functional measure of the "brain in action", i.e. the processing of internal and external events**.**

The initial demonstration that the P300 component changed with age was reported by Goodin, Squires, Henderson, and Starr (1978a), who used an auditory oddball task in which P300 components were recorded at the scalp from normal participants who varied in age. Goodin, Squires, Henderson, and Starr (1978a) were the first to suggest that ERPs might be a useful tool for investigating age-related changes in cognition and that P300 latency provides a sensitive neuroelectric index of these changes. The P300 has been studied extensively across the lifespan in order to evaluate the neurophysiological basis of the changes in cognition that occur with aging.

Goodin and colleagues (Goodin, Squires, Henderson, & Starr, 1978a; Goodin, Squires, & Starr, 1978b) initially reported that the P300 component of the evoked potential to detected auditory signals was longer in latency in older participants than in young. This has been replicated using both auditory and visual tasks (Squires, Chippendale, Wrege, Goodin, & Starr, 1984; Syndulko et al., 1982; Pfefferbaum, Ford, Wenegrat, Roth, & Kopell, 1984; Polich, Howard, & Starr, 1983). Although there is an overall increase in P300 latency with increasing age, there appears to be a marked change in old age (Beck, Swanson, & Dustman, 1980). Beck, Swanson, and Dustman (1980) reported a latency increase of .8 ms per year until the age of 63 years and then a latency increase of 1.6 ms per year afterwards. Brown, Marsh, and LaRue (1983) found no significant age-related change in the P300 latency of individuals below the age of 45 years, although the P300 latency increased at a rate of 3.14 ms per year after age 45. Although there is an apparent discrepancy in the literature regarding the latency of P300, the overall agreement is a support of age-related latency increases.

Additionally, a number of studies have shown that the P300 amplitude decreases with age (Goodin, Squires, Henderson, & Starr 1978a; Goodin, Squires, & Starr, 1978b; Brown, Marsh, & LaRue, 1983). In a study by Brown, Marsh, & LaRue (1983), the later ERP components showed prolonged latency and decreased amplitude in older participants while earlier components were not affected. According to Goodin, Squires, Henderson, and Starr (1978a), age is a factor which should be carefully considered when attempting to reach conclusions from an evoked potential waveform. This is particularly true in a clinical situation where a majority of neurological patients are substantially older than the population of college aged participants on whose data most of evoked potential research is based (Goodin, Squires, Henderson, & Starr, 1978a).

Physical Activity and Cognitive Function

Several studies have found age-related decrements in performance on some cognitive tasks are attenuated in participants with high- compared to low-physical exercise (Dustman et al., 1984; Spirduso, 1980; Baylor & Spirduso, 1988), although strong effects are not always obtained (cf. Blumenthal & Madden, 1988; Dustman, Emmerson, & Shearer, 1994). Older persons who are aerobically fit have shown superior ability in attention, processing speed, short-term and effortful memory, fluid intelligence, and perceptual set shifting (Bashore & Goddard, 1993; Chodzko-Zajko, Schuler, Solomon, Heinl, & Ellis, 1992; Christensen & Mackinnon, 1993; Dustman et al., 1984; Etnier et al., 1997; Hassmen, Ceci, & Backman, 1992; Kramer et al., 1999; Landers & Arent, 2001; Powell & Pohndorf, 1971). Kramer et al. (1999) found compelling evidence to support the notion regarding the specificity of exercise and executive processes while measuring several executive functions before and after six months of either an aerobic walking program or anaerobic toning and stretching program. Individuals in the aerobic group showed greater improvement than the anaerobic group on task switching, stopping, which measures the ability to abort a preprogrammed action, and response compatibility, which measures the ability to ignore stimuli irrelevant to the task. Further, there were no differences between groups for the reaction time on non-switch trials but this difference from the other cognitive measures was expected since non-switch reaction time does not depend on executive control functions. Additionally, selective benefits were not found for spatial attention, visual search, digit-digit and digit-symbol comparison tasks, all of which do not rely on executive processes (Kramer et al., 1999).

Exercise and Central Nervous System Effects in Animals

Dustman, Emmerson, and Shearer (1994) noted that the findings from animal studies strongly suggest there is a positive relationship between physical exercise and CNS health which occurs, at least in part, because of improved neurotransmitter functioning, preservation of dopaminergic cells, increased vascularization, and increased cell hypertrophy and complexity. Voluntary exercise in rats increased levels of brain-derived neurotrophic factor (BDNF) and other growth factors, stimulated neurogenesis, and improved learning and mental performance (Cotman & Berchtold, 2002). Evidence of improved dopamine receptor site binding as well as heightened striatal dopamine levels in brains of older rats has been associated with treadmill running (Spirduso, 1983). Furthermore, Isaacs, Anderson, Alcantara, Black, and Greenough (1992) found that both motor skill learning and repetitive physical exercise stimulated angiogenesis in the adult rat cerebellar cortex.

Exercise, Aging, and Central Nervous System Function

In humans it also appears that exercise has benefits for overall health and cognitive function, particularly in later life. Rogers, Meyer, and Mortel (1990) found higher levels of cerebral blood flow, associated with superior cognitive function, in retirees who were active as compared to sedentary individuals. These exercise-induced effects have been labeled the neurotrophic and cerebral circulation or oxygenation hypotheses, respectively (Van Boxtel et al., 1997).

Additionally, Kramer et al. (1999) have advanced the notion that differences in cognitive function between fit and less fit elderly individuals is most apparent for tasks that involve frontal function (i.e. executive processes). This difference makes sense in light of the relative magnitude of age-related decline in the frontal lobe as discussed earlier. Furthermore, Gazzaniga and colleagues (Gazzaniga, Ivry & Mangun, 2002) note that the cerebellum and basal ganglia are highly involved in the performance of executive challenges. It seems logical to assume that physical activity would preserve the integrity of these physical movement related structures.

Effect of Exercise on P300

Current research has supported the notion that exercise has specific beneficial effects on cognitive function. The following is a review of the literature associated with the P300 event-related potential and physical activity. Nakamura, Nishimoto, Akamatu, Takahashi, and Maruyama (1999) examined the effect of jogging on P300 event-related potentials. They administered an auditory oddball paradigm to seven well-trained joggers. ERPs were measured before and after thirty minutes of jogging. Amplitudes of the P300 increased after jogging compared to values recorded before jogging. This suggests that jogging has a facilitative effect on cognitive processes involving the P300. Additionally, Magnie et al. (2000) compared P300 event-related potentials before and after a maximal cycling test in a group of cyclists and a group of sedentary individuals. Results showed a significant P300 amplitude increase and latency decrease in all subjects. This further supports that notion of the arousing effect of exercise on the brain. Additional support was provided by Polich and Lardon (1997) for the effects of intensive physical exercise on P300 amplitude.   ERPs were recorded separately during auditory and visual oddball task conditions and compared in subjects who engage in high and low amounts of physical activity, respectively. P300 amplitude was affected by exercise frequency, such that increased amounts of exercise were associated with increased amplitude.   Although these studies reveal the sensitivity of the P300 response to physical activity they are limited in their relevance to the purpose of the present study in that they examined the relationship between activity and cortical response in an acute exercise setting (Magnie et al., 2001; Nakamura, Nishimoto, Akamatu, Takahashi, & Maruyama, 1999) and focused on younger populations (Magnie et al., 2001; Nakamura, Nishimoto, Akamatu, Takahashi, & Maruyama, 1999; Polich & Lardon, 1997).

In a study of age, fitness level, and P300 latency, Bashore (1989) found that elderly men who were physically fit did not show an expected age related slowing of the P300 component. Dustman et al. (1990) found that physically active men had shorter ERP latencies, stronger central inhibition, better neurocognitive performance, and better visual sensitivity compared to low fit men. However, the older individuals in Dustman's study were limited to persons aged 50-60 years. In an attempt to overcome this limitation McDowell, Kerick, Santa Maria, and Hatfield (2003) compared younger (18 – 30 years) and older individuals (65 – 75 years) and supported the notion that physical activity attenuates the decline of cognitive function in older men and women. They reported that physically active relative to inactive older individuals exhibited a more efficient cognitive response during an auditory oddball task as indexed by a reduced area under the curve for P300 amplitude. Based on this finding they suggested that a reduction in neural resources in response to a cognitive challenge (i.e., efficiency) is associated with greater physical activity in the elderly. However, it would seem that a response inhibition task such as the nogo would be even more sensitive to detecting activity-related differences in cortical function in the elderly

Accordingly, the comparison of such P300 responses from the frontal area of older individuals (aged 66 and older), who differ in physical activity status, while performing an executive cognitive challenge (i.e. go-nogo task), may yield important insights into the effects of physical activity participation on the aging brain. In light of the predominant decline in frontal processes associated with aging, exercise may show the greatest effect during the performance of executive tasks. As such, the P300 elicited during the nogo trials of a go-nogo task is an event-related potential component that may be particularly sensitive to the benefits of exercise on frontal brain cognitive function.

CHAPTER III

METHODS AND PROCEDURES

The following chapter includes a description of the methods used to accomplish the stated purpose of the study, that is, to examine the relationship between aging, an event-related potential (P300), and physical activity.

Participants

Participants consisted of 78 individuals (55 female, 23 male) 66 years of age and older. The mean participant age was 79 years (sd = 5.5). In addition, the mean number of years of education was 15.5 (sd = 2.8) with most participants having at least an undergraduate degree. They possessed a wide range of physical activity status and were free of any disease which may affect the central nervous system. Participants were screened with a standard screening questionnaire to record health status, demographic variables, medication usage, and use of tobacco or alcohol. Any participant who indicated usage of medication that could affect the CNS was eliminated from further participation. All participants were right-handed. Participants gave their informed consent by signing a form approved by the Institutional Review Board. Participants completed the Mini-mental status exam (MMSE; Folstein, Folstein, & McHugh, 1975) to screen for dementia. A score below 26 would indicate dementia and would eliminate those participants from further participation. A measure to test IQ was used, the Kaufman Brief Intelligence Test (K-BIT; Kaufman & Kaufman, 1990). It was used to determine the relative intelligence of the participant population for demographic purposes. Each participant was screened for stable EEG across a 2-min sampling period prior to recording resting brain activity in accordance with the tasks. See table 1 for a summary of participant characteristics.

Table 1. Means and Standard Deviations of Participant Characteristics

Variables	Combined (sd)	Men (sd)	Women (sd)
Height (cm)	165.58 (9.32)	176.52 (6.5)	161.04 (5.9)
Weight (kg)	70.4 (14.5)	80.1 (12.01)	66.4 (13.6)
Age	79 (5.5)	79.7 (5.6)	78.9 (5.5)
Education (yrs)	15.5 (2.8)	16.5 (3.45)	15.0 (2.4)
Yale Energy Expenditure (kcals)	5232 (2684)	4849 (2173)	5386 (2867)
Yale Hours of Activity	24.90 (11.1)	23.05 (11.7)	25.64 (10.8)
MMSE total	28.62 (1.58)	28.45 (1.6)	28.69 (1.6)
Kaufman Composite Percentile Rank	85.67 (12.96)	89.38 (9.3)	84.22 (13.9)

Behavioral Challenges

Participants performed a binaural auditory procedure. Two tasks were employed: an oddball and a go-nogo task. During the oddball task, participants were subjected to three blocks of 100 tones (80 common, 20 rare in each block) and were asked to press a button when they heard the target or rare tones. Participants were asked to count the number of rare tones they heard in each of the trials and were asked to report the number at the termination of each block In the go-nogo task, participants heard three blocks of

100 tones (80 common, 20 rare) and were asked to respond to the common tones only, withholding their response to the rare or target tones (inhibition). Participants were not asked to count the tones in the go-nogo task. Participants were instructed to look straight ahead at a target, and focus on the tones they heard in each of the tasks. Tones were presented in the ear canal via a soft earplug insert. Low tones (common tones) were 1000 Hz and high tones (rare or target tones) were 2000 Hz. The interstimulus interval was set at 2.00 seconds. Tones were 80 db in the go-nogo task. Tones were 95 db in the oddball task.

Measures

Physical Activity

In order to determine the physical activity level of the participants, the Yale Physical Activity Survey (YPAS; DiPietro, Caspersen, Ostfeld, & Nadel, 1993) was employed. The YPAS is a comprehensive instrument designed to examine a range of activities including household, leisure, and exercise settings (Young, Jee, & Appel, 2001). The strengths of this instrument are its ability to assess moderate and vigorous physical activities and low-intensity physical activities such as leisurely walking and general daily activities (i.e., household chores, stair climbing). The participants were asked to estimate the amount of time spent in a list of twenty-five activities that they may have performed in a typical week during the last month. Weekly Energy Expenditure (kcal.week^{-1}) is calculated by multiplying the time spent in each activity by an intensity code and then summing across all the activities. Additionally, the Total Time index is calculated by summing the time spent in each activity. Furthermore, individuals were asked to categorize the frequency and duration of time spent in each of five physical activity dimensions; Vigorous Activity, Leisurely Walking, Moving, Standing, and Sitting. An index of each dimension is created by multiplying the duration and frequency together and then multiplying by the appropriate weighting factor for each given dimension. A Summary Index is calculated by summing across each activity dimension (Young, Jee, & Appel, 2001).

The validity of the YPAS has recently been examined (Young, Jee, & Appel, 2001). In a study of 59 participants between the ages of 60-80, it was found that the global activities and vigorous activity indices correlated with the corresponding measures of the Stanford 7-day physical activity recall (PAR; Blair, Haskell, Ho, Paffenbarger, Vranizan, Farquhar, & Wood, 1985). The results for the low-intensity activity were not as clear, as corresponding measures for low-intensity activity have yet to be determined (Young, Jee, & Appel, 2001). In summation, the YPAS appears to provide a reliable and valid estimation of activity in an older adult population as it is a measure of stable activity patterns over time. The independent variable, activity level, was represented in this study by the calculated weekly energy expenditure in kilocalories, which ranged from 1530 kcal to 19,887 kcal with a mean of 5232 kcal (sd = 2684).

EEG

EEG was recorded from nine sites of the scalp corresponding to Fz, F3, F4, Cz, C3, C4, Pz, P3, and P4 of the International 10-20 electrode placement system (Jasper, 1958), referenced to the right mastoid (A2), and grounded to FPz. EEG signal processing was conducted off-line with Neuroscan software (Neuroscan Labs, Neurosoft, Inc., version 4.1.1, Sterling, VA). EEG was re-referenced by linear derivation to average mastoids. Ocular correction was performed and eye blinks were corrected using the eye correction algorithm in NeuroScan 4.1.1 (Semlitsch, Anderer, Schuster, & Presslich, 1986). Filter settings during data collection were .01 Hz and 100 Hz for the high-pass and low-pass settings, respectively. The time series data were epoched into 1100-msec segments, and baseline corrected based on a 100-msec prestimulus interval. Artifact rejection procedures resulted in the removal of any epochs containing amplitudes greater than +- 100 μV from further analysis. The common and rare epochs for the oddball and go-nogo tasks were sorted according to trial type. The go trials, nogo trials, oddball common trials, and the oddball rare trials, were then averaged in the time domain to yield four averaged time series with event-related potentials resulting in response to the nogo trials of the go-nogo task and the rare trials of the oddball task. The averaged time series were filtered further from 1-15 Hz. Waveforms were analyzed by peak picking with a latency window of 300-650 ms (Donchin et al., 1978; Eimer, 1993; Kopp, Mattler, Goertz, & Rist, 1996) and entered into an SPSS spreadsheet**.** Additionally, average amplitudes over this time window were created by averaging P300 amplitudes using Neuroscan version 4.2 algorithm. These too were entered into SPSS version 11.5 for analysis.

Testing Procedures

Participants were required to complete two days of testing each consisting of approximately two hours. On day 1, participants provided their informed consent, completed a battery of questionnaires designed to examine physical activity (YPAS), intelligence (K-BIT), and mental status (MMSE). The data used in this investigation was part of a larger investigation.

On day 2 the participants were fitted with a electrode cap housing tin electrodes for the electroencephalographic recording. Gold electrodes were placed above and below the right eye for recording of eye blinks, to the side of each eye for the recording of horizontal eye movement, and on the mastoids to serve as reference. With these electrodes in place, the participants were fitted with a nylon/spandex electrode cap (electro-cap international, Dallas, TX) for the placement of scalp electrodes. When the cap was in place, electro-conductive gel was inserted, via a hollow tipped plastic syringe, into the eye and reference electrodes as well as electrode sites Fz, F3, F4, Cz, C3, C4, Pz, P3, P4, and Fpz, which served as ground (International 10-20 system, Jasper, 1958). Impedances were checked and brought below 10 Kohms. Participants were instructed to sit quietly in a chair and look straight ahead. They were asked to count the target tones in the oddball task and report them upon completion of each trial. For each task, accuracy and response latencies as generated by a button press (or inhibition of button press in appropriate trials – i.e., nogo) were recorded for all trials in the experimental blocks. Accuracy was determined by the percentage correct out of the total number of trials in the block. Failing to respond on a trial resulted in an incorrect answer. In addition, responding when instructed to withhold a response also resulted in an error (i.e., nogo trials). Continuous EEG was recorded during the three blocks of 100 trials each during a binaural auditory go-nogo task and an oddball task. EEG was acquired at a sampling rate of 256 Hz and amplified 20,000 times, while the eye channels were amplified 5,000 times using Grass model 12A5 Neurodata Acquisition amplifiers with band-pass filter settings of 0.1-100 Hz (96-db/octave). Amplifiers were calibrated prior to each testing session with a 10-Hz, 50-μV sinusoidal input signal that was presented to all channels simultaneously. Data sampling was controlled by Neuroscan software (Neuroscan Labs, Neurosoft, Inc., Sterling, VA) installed on a Gateway 2000 Pentium computer (Gateway, North Sioux City, SD).

Statistical Analysis

Separate regression analyses were employed to examine the direction and magnitude of the relationship between physical activity and average left frontal P300 amplitude during the target trials of (1) the nogo and (2) the oddball tasks. In order to control for any effects of age on the P300 response the full regression model included both age and physical activity (weekly Kcal activity expenditure) as predictors. Age was entered first in the equation. The peak amplitude and latency of the P300 component at site F3 were also separately regressed on age and physical activity during the target trials of the go-nogo and oddball tasks in a similar manner. Average amplitudes, peak amplitudes, and peak latencies of the P300 component recorded at all other locations (Fz, F4, Cz, C3, C4, Pz, P3, and P4) during the target trials of the two tasks were similarly subjected to such analyses in order to assess the extent of the relationship of physical activity with cortical response across the entire montage.

Note: P300 amplitudes (average and peak) and latencies were also regressed on a subset of the weekly activity expenditure, that is, the vigorous exercise participation category, and a number of significant effects were noted. See Appendix A for a summary of these results.

CHAPTER IV

RESULTS AND DISCUSSION

Overview

The results will be organized in the following manner. The hypotheses will be restated and the respective results reported for both the go-nogo and oddball tasks at site F3 will include a full model regression analysis of the P300 (i.e., amplitude or latency) based on age and physical activity, as well as the explained variance (R square) in the variable of interest from the predictors. Scatterplots will be used to illustrate the relationship (i.e., intercept and slope) between the P300 component of interest and physical activity. The results obtained from the exploratory analyses (remaining sites) will follow. As indicated earlier, executive task performance was predicted to show differences based on physical activity level as determined by the weekly energy expenditure, meaning that more physically active individuals should exhibit higher amplitudes and shorter latencies than those who are less active.

Results

Descriptive statistics of the current data provided support that the amplitude of the P300 component of the event-related potential was characterized by a parietal maximum. In the rare nogo trials, the maximum average amplitude of the P300 was at site Pz (mean = 7.24 μV). Parietal sites P3 and P4 follow, respectively. In the middle of the amplitude range, central sites Cz, C3, and C4 were exhibited. Lastly, frontal sites (Fz, F3, and F4) revealed the lowest amplitudes. The oddball rare trials were also defined by maximum amplitude at site Pz (mean = 5.79 μV). This was followed by sites P4 and P3. Central sites C4, C3, and Cz followed in regard to magnitude of the amplitude, with the frontal sites F4, Fz, and F3 revealing the lowest amplitudes.

Hypothesis One

A positive relationship was predicted between P300 amplitude and physical activity for F3 during the nogo trials of the go-nogo task. Support was found for this hypothesis. Multiple regression analysis revealed that the overall relationship of P300 amplitude to age and physical activity was significant at site F3 during the executive control task, F (2, 75) = 3.61, p = .032. The full model (age and activity) accounted for 9% of the variance in P300 amplitude at this site. The slope of the relationship between physical activity and amplitude was significant (t = 2.55, p = .013) indicating that those who were more physically active presented higher amplitudes as the standardized regression coefficient (β) for kilocalorie expenditure was .281. See figure 1 for a scatterplot of this regression.

In contrast, a non-significant relationship between P300 amplitude and physical activity was revealed at site F3 during the target trials of the oddball task, F (2, 74) = .021, p = .979.

In addition, an extreme contrast of the most physically active (n=5) and least physically active (n=5) was plotted to compare the grand average waveforms produced. See figure 2 for a depiction of these waveforms. Line A marks the high active group while line B marks the low active group. High active individuals exhibited higher amplitudes (mean= 8.738 μV) than low active individuals (mean= 5.474 μV). High active participants also had shorter latencies (mean= 400 ms) than the low active group (mean= 440 ms).

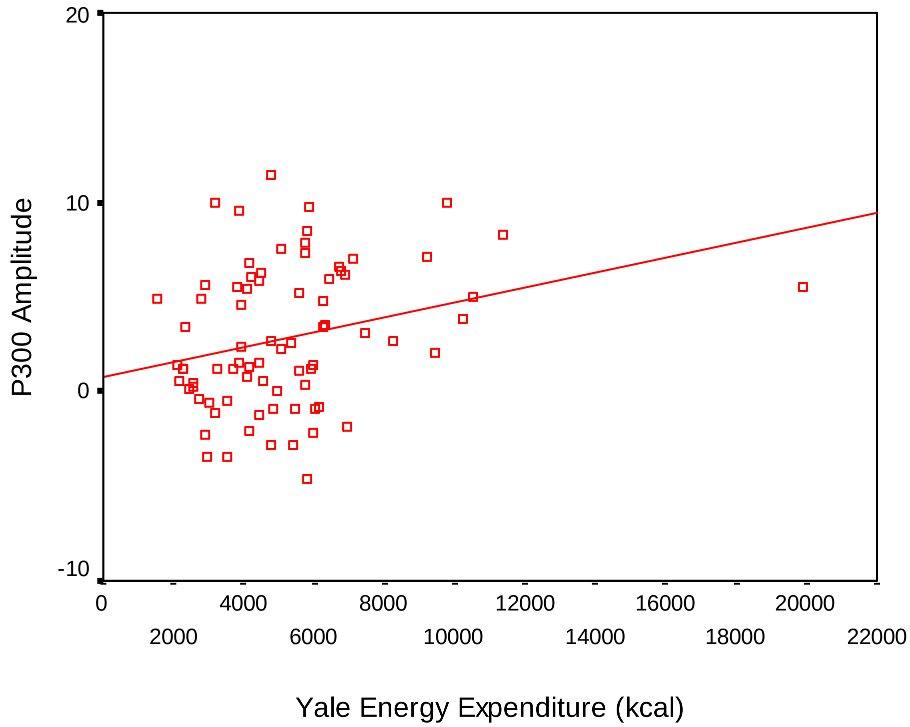


Figure 1. Scatterplot of P300 amplitude at site F3 during nogo trials regressed on physical activity

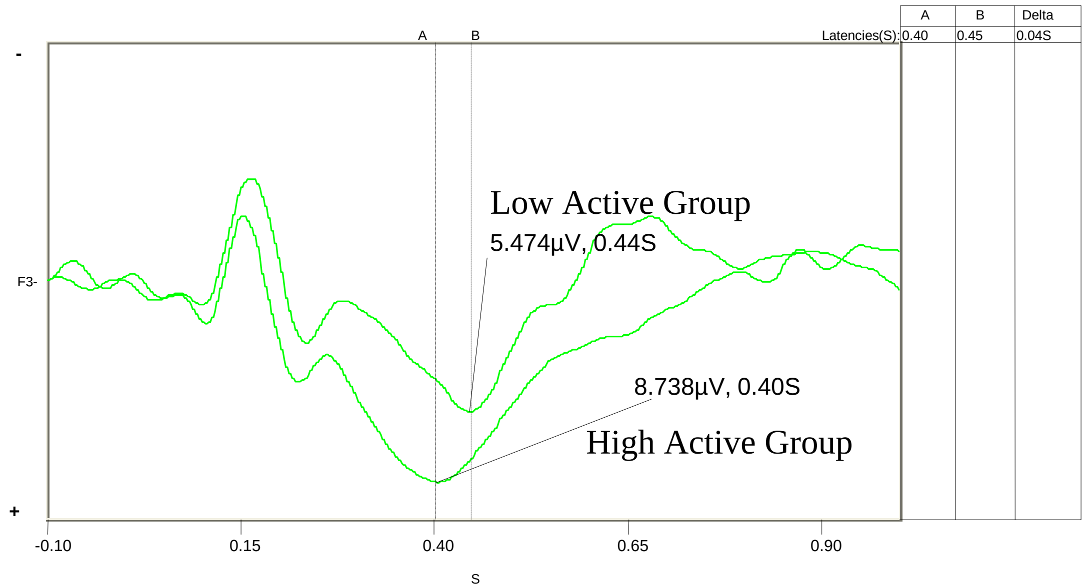


Figure 2. Grand average waveforms of extreme contrast between high vs. low physical activity groups during nogo trials

Table 2 provides a summary of the regression analyses for average amplitudes during the nogo trials of the go-nogo task at the remaining electrode sites. Exploratory analyses revealed additional support for hypothesis one. Multiple regression analysis revealed that the overall relationship of P300 amplitude to age and physical activity was significant at site Fz during the executive control task, F (2, 75) = 6.26, p = .003. The full model (age and activity) accounted for 14% of the variance in P300 amplitude at this site. The slope of the relationship between physical activity and amplitude was significant (t = 3.39, p = .001) indicating that those who were more physically active presented higher amplitudes as the standardized regression coefficient (β) for kilocalorie expenditure was .363. See figure 3 for a scatterplot of this regression analysis.

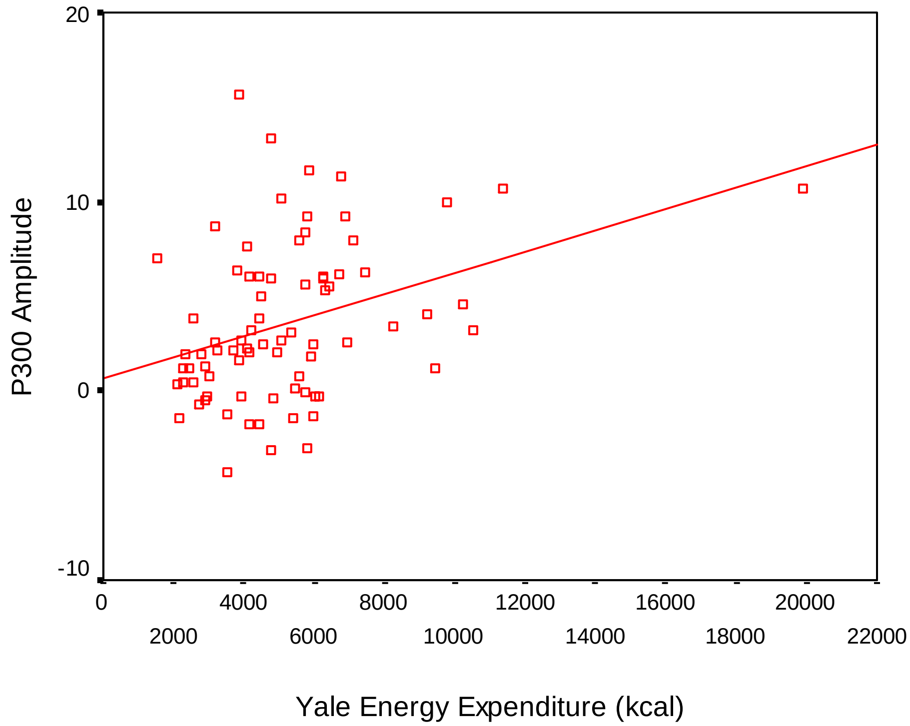
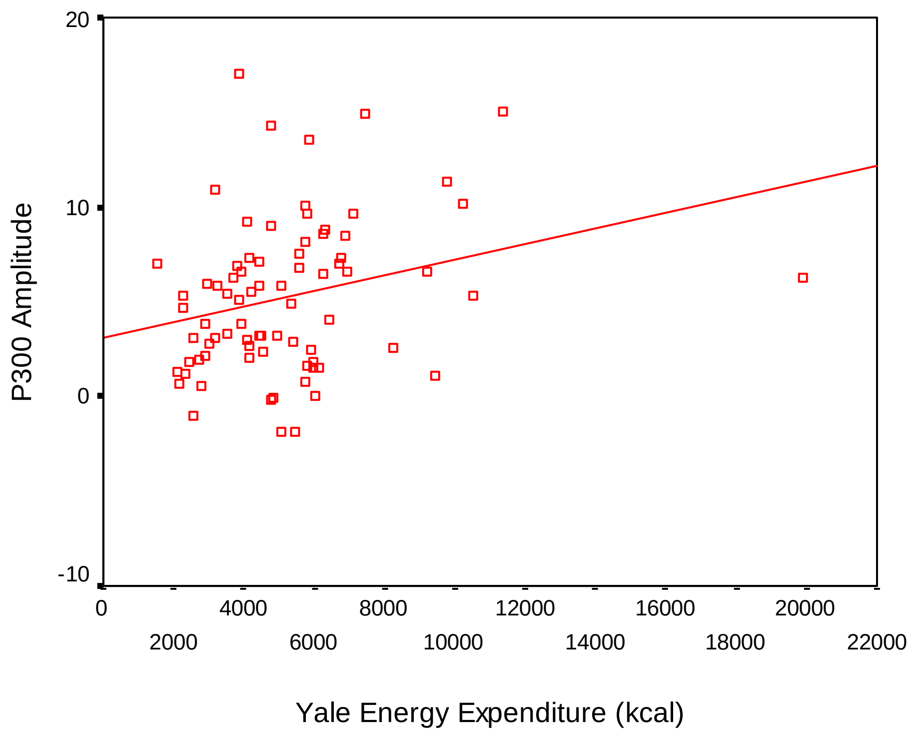


Figure 3. Scatterplot of P300 amplitude at site Fz during nogo trials regressed on physical activity

Multiple regression analysis also revealed that the overall relationship of P300 amplitude to age and physical activity was significant at site C4 during the executive control task, F (2, 75) = 3.57, p=.033. The full model (age and activity) accounted for 9% of the variance in P300 amplitude at this site. The slope of the relationship between physical activity and amplitude was significant (t = 2.47, p = .016) indicating that those who were more physically active presented higher amplitudes as the standardized regression coefficient (β) for kilocalorie expenditure was .273. See figure 4 for a scatterplot of this regression analysis.



<u>Figure 4</u>. Scatterplot of P300 amplitude at site C4 during nogo trials regressed on physical activity

Table 2. Regression analysis of P300 amplitude on age and physical activity: Overall summary of results for amplitudes elicited at all remaining sites during nogo trials.

Dependent Variable	Predictor	df	Beta	t	p
FZ Amplitude	Activity	2,75	0.363	3.394	0.001
	Age	2,75	-0.105	-0.979	0.331
F4 Amplitude	Activity	2,75	0.200	1.781	0.079
	Age	2,75	-0.103	-0.914	0.364
CZ Amplitude	Activity	2,75	0.163	1.439	0.154
	Age	2,75	-0.107	-0.948	0.346
C3 Amplitude	Activity	2,75	0.217	1.924	0.058
	Age	2,75	-0.035	-0.313	0.755
C4 Amplitude	Activity	2,75	0.273	2.471	0.016
	Age	2,75	-0.112	-1.011	0.315
PZ Amplitude	Activity	2,75	0.220	1.950	0.055
	Age	2,75	-0.008	-0.069	0.945
P3 Amplitude	Activity	2,75	0.208	1.838	0.070
	Age	2,75	0.017	0.150	0.881
P4 Amplitude	Activity	2,75	0.222	1.968	0.053
	Age	2,75	-0.031	-0.276	0.783

Hypothesis Two

A negative relationship was predicted with P300 latency and physical activity at site F3 in the nogo condition of the go-nogo task. This relationship was not supported, ($F = .151$, $p = .860$). The slope of this relationship was not significant ($t = .327$, $p = .745$) as the standardized regression coefficient (β) for kilocalorie expenditure was .038.

As a comparison, the relationship between P300 latency and physical activity at site F3 in the oddball target trials was examined. This relationship was not supported, (F= 1.775, p = .177). The slope of this relationship was not significant (t = 1.550, p = .126) as the standardized regression coefficient (β) for kilocalorie expenditure was .184.

Exploratory analyses will now be discussed and significant findings presented with an illustration of each relationship provided. Table 3 has been provided to summarize the overall results of the relationship between P300 latency, age, and physical activity to the target responses during a nogo task at all remaining recording sites.

Multiple regression analysis revealed that the overall relationship of P300 latency to age and physical activity was significant at site P4 during the executive control (nogo) task, $F\ (2, 74) = 4.23$, p=. 018. The full model (age and activity) accounted for 10% of the variance in P300 latency at this site. The slope of the relationship between physical activity and latency was significant (t = -2.20, p = .031) indicating that more physically active individuals present shorter latencies as the standardized regression coefficient (β) for kilocalorie expenditure was -.243. Figure 5 shows a scatterplot of this regression analysis.

Table 3. Regression analysis of P300 latency on age and physical activity: Overall summary of results for latencies elicited at all remaining sites during nogo trials

Dependent Variable	Predictor	df	Beta	t	p
FZ Latency	Activity	2,74	0.082	0.717	0.476
	Age	2,74	0.148	1.291	0.201
F4 Latency	Activity	2,74	-0.010	-0.089	0.929
	Age	2,74	0.067	0.581	0.563
CZ Latency	Activity	2,74	-0.088	-0.776	0.440
	Age	2,74	0.220	1.946	0.055
C3 Latency	Activity	2,74	-0.136	-1.204	0.232
	Age	2,74	0.187	1.652	0.103
C4 Latency	Activity	2,74	-0.013	-0.110	0.913
	Age	2,74	0.164	1.434	0.156
PZ Latency	Activity	2,74	-0.200	-1.802	0.076
	Age	2,74	0.230	2.078	0.041
P3 Latency	Activity	2,74	-0.176	-1.567	0.121
	Age	2,74	0.192	1.714	0.091
P4 Latency	Activity	2,74	-0.243	-2.205	0.031
	Age	2,74	0.210	1.911	0.060

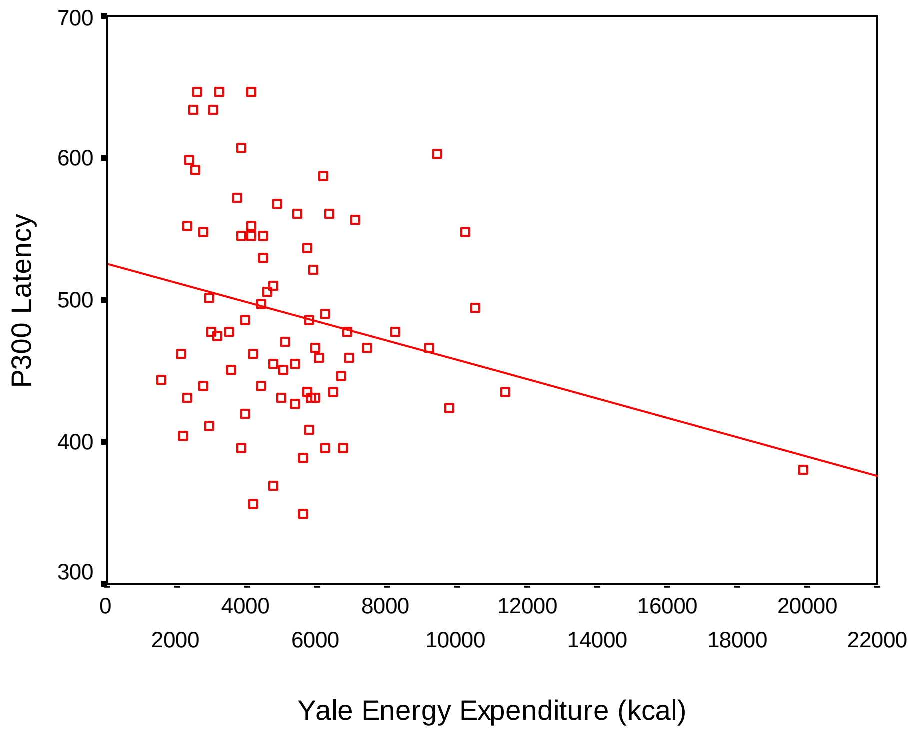


Figure 5. Scatterplot of P300 latency at site P4 during nogo trials regressed on physical activity

In addition, multiple regression analysis revealed that the overall relationship of P300 latency to age and physical activity was significant at site Pz during the executive control task, *F* (2, 74) = 3.76, *p*=. 028. The full model (age and activity) accounted for 9% of the variance in P300 latency at this site. However, the slope of the relationship between physical activity and latency was not significant (t = -1.80, p = .076). The slope of the relationship between age and latency was significant (t = 2.08, p = .041). These results indicate that with advancing age, latency increases. See figure 6 for a scatterplot of this relationship.

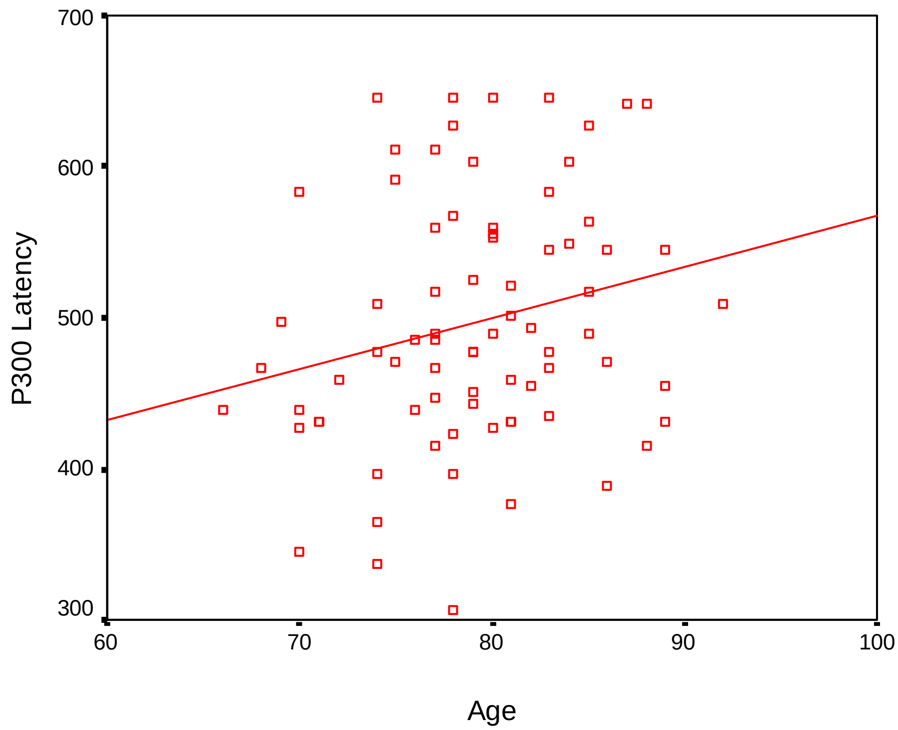


Figure 6. Scatterplot of P300 latency at site Pz during nogo trials regressed on age

The following section reports the P300 amplitude and latency responses during the target trials of the oddball task at all remaining recording sites other than F3. No significant relationships were predicted between weekly physical activity and these measures during this non-executive task. Table 4 summarizes the results for average amplitude.

Table 4. Regression Analysis of P300 amplitude on age and physical activity: Overall summary of results for amplitudes elicited at all remaining sites during rare oddball trials

Dependent Variable	Predictor	Df	Beta	t	p
FZ Amplitude	Activity	2,74	-0.037	-0.320	0.750
	Age	2,74	-0.033	-0.285	0.776
F4 Amplitude	Activity	2,74	0.100	0.867	0.389
	Age	2,74	-0.022	-0.191	0.849
CZ Amplitude	Activity	2,74	0.137	1.185	0.240
	Age	2,74	0.063	0.546	0.587
C3 Amplitude	Activity	2,74	-0.024	-0.209	0.835
	Age	2,74	0.078	0.672	0.504
C4 Amplitude	Activity	2,74	0.088	0.762	0.448
	Age	2,74	-0.013	-0.116	0.908
PZ Amplitude	Activity	2,74	0.054	0.461	0.646
	Age	2,74	0.055	0.472	0.638
P3 Amplitude	Activity	2,74	-0.016	-0.136	0.892
	Age	2,74	-0.023	-0.194	0.847
P4 Amplitude	Activity	2,74	0.062	0.533	0.596
	Age	2,74	0.029	0.253	0.801

Table 5 provides a summary of the results of the relationship between P300 latency, age, and physical activity at the remaining sites to the target responses during an oddball task.

Table 5. Regression Analysis of P300 latency on age and physical activity: Overall summary of results for latencies elicited at all remaining sites during rare oddball trials

Dependent Variable	Predictor	df	Beta	t	p
FZ Latency	Activity	2,74	0.084	0.697	0.488
	Age	2,74	0.057	0.474	0.637
F4 Latency	Activity	2,74	0.043	0.360	0.720
	Age	2,74	0.219	1.844	0.070
CZ Latency	Activity	2,74	0.106	0.876	0.384
	Age	2,74	0.034	0.285	0.776
C3 Latency	Activity	2,74	0.006	0.052	0.959
	Age	2,74	0.239	2.027	0.047
C4 Latency	Activity	2,74	0.022	0.183	0.855
	Age	2,74	0.077	0.637	0.526
PZ Latency	Activity	2,74	-0.085	-0.699	0.487
	Age	2,74	-0.002	-0.013	0.990
P3 Latency	Activity	2,74	-0.121	-1.006	0.318
	Age	2,74	0.074	0.613	0.542
P4 Latency	Activity	2,74	-0.083	-0.690	0.493
	Age	2,74	0.078	0.644	0.522

Although the overall relationship of P300 latency at site C3 to age and physical activity was not significant, *F*, (2,68), $p = .135$, a relationship was found between P300 latency and age, t = 2.027**,** $p = .047$. Standardized regression coefficient (β) for age was .239. R^2 accounted for 6% of the variance in the full model. The slope of this relationship indicated that with an increase in age, latency increases. See figure 7 for a scatterplot of this regression analysis.

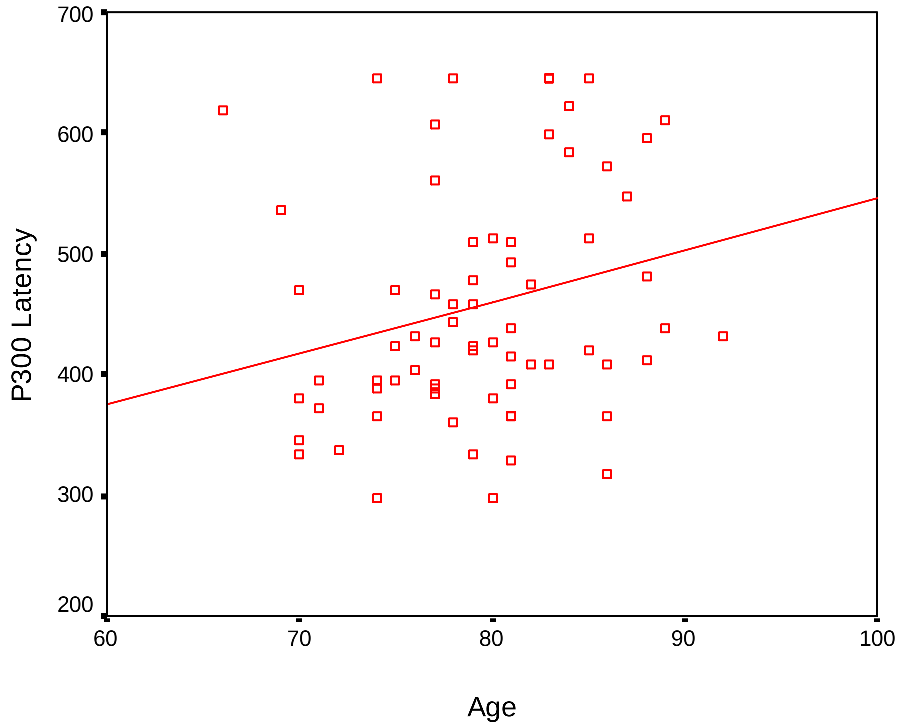


Figure 7. Scatterplot of P300 latency at site C3 during rare oddball trials regressed on age

Reaction Time Results

Participants in this study had a mean reaction time of 457 ms (sd= 8.6) with a minimum reaction time of 250 ms and a maximum of 760 ms on the rare trials of the oddball task. The overall relationship between reaction time on the rare oddball trials, physical activity, and age was not significant, F, (2,75), p = .328.

The average error rate on the target nogo and oddball tasks was 4.7% +/- 5.7% (mean +/- sd) for commission errors (pressing the button with incorrect stimuli). The average error rate was 5.6 +/- 7.6 % (mean +/- sd) for omission errors (missing the target stimuli).

Discussion

The current study was designed to investigate the relationship between physical activity, age, and cognitive performance on both executive and non-executive tasks in older adults. More specifically, the hypotheses proposed that older adults with higher physical activity levels would exhibit higher amplitudes in the left frontal region during an executive task and that a relationship would also occur between physical activity level and P300 latency at this site. Because of the specific relationship posited between frontal lobe integrity and physical activity participation no such relationships were predicted during the execution of the nonexecutive (i.e., oddball) task. These predictions were largely supported by the present findings.

In the aging process there is a generalized slowing of nervous system functioning that is observed at peripheral, brain stem, sensory receiving, and cognitive-integrative levels. Inhibition weakens during normal aging (Dustman & Shearer, 1987; Roberts, 1972; Shagass, 1972). An inability to inhibit external and internal stimuli might result in distractibility and impaired attention and concentration (Botwinick, 1973; Hoyer & Plude, 1980; Schaie, 1958; Strommen, 1973; White, 1965). The nogo condition of the present study provided an executive task challenge, which requires response inhibition.

The independent variable of interest in this study was weekly physical activity involvement. Specifically, physical activity is an appropriate variable to examine in the current population as it engages a broader population segment as opposed to exercise for fitness benefits which is characteristic of a rather small population especially in the age range examined herein. The Yale Physical Activity Survey (YPAS), employed in the present study, has been proven a valid measure of activity specific to older populations. The YPAS is a measure of stable activity patterns over time and was useful to use with the current study participants who were engaged in stable patterns of activity for at least five years. This procedure along with the assessment of typical weekly Kcal expenditure captured long-term physical activity patterns as opposed to acute bouts of physical activity. Most participants in the present study did not engage in intense aerobic activities, suggesting that moderate physical activity is beneficial for cognitive brain function. Participants who performed moderate physical activity incorporated it into their lifestyle. According to Etnier, Salazar, Landers, Petruzzello, Han, and Nowell (1997), physical activity that is acute may be inconsequential when small and temporary changes in physiological parameters occur. The influence of activity becomes larger as the size or permanence of changes increase.

Physical activity provides many benefits specific to brain function. There is evidence that physical activity has an angiogenic effect on the cerebellum which also plays a role in executive function (beyond that of the frontal lobes) (Isaacs et al, 1992). This suggests that physical activity may target areas of the brain where executive control functions are processed, leading to less of a decline in performance in these areas. Investigators have suggested that because of the beneficial effects that strenuous physical activity has on the cardiovascular system, appropriate exercise may benefit CNS health. Specifically, physical activity has beneficial effects on the hippocampus (Cotman &

Berchtold, 2002), which is an area of the brain that is affected by Alzheimer's disease. Cotman and Berchtold (2002) suggest that exercise may help protect against aging in the brain through upregulation of brain-derived neurotrophic factor (BDNF) as well as other growth factors. This stimulates neurogenesis, and can lead to improved learning and mental function. This neurotrophic effect is predominantly in the hippocampal area of the brain, but extends to other areas including the frontal lobe. Therefore, because hippocampal degeneration is a primary factor in Alzheimer's disease it would appear that physical activity would help protect the hippocampus and be beneficial towards warding off such dementia.

Overall, support was shown for frontal lobe effects related to physical activity in the present study. Increased kilocalorie expenditure was positively related to amplitude in the frontal area (F3) of the brain during the nogo trials of a go-nogo task, which is an executive task. This supports the finding of Kramer et al. (1999) in which aerobic exercise training increased executive control performance, particularly in the frontal region of the brain. This area is one of the fastest to decline with advancing age. Specifically, blood flow, brain weight, and cortical thickness decreases in this region (Dempster, 1992). In addition, midline frontal activation was also related to physical activity and P300 amplitude providing further support for the frontal lobe hypothesis. Right central activation was also positively related to physical activity levels. A reason for this could be that executive tasks require effortful cognitive processing in several areas throughout the brain. Interestingly, the amplitude of F3 recorded during the oddball task was not related to physical activity in this study. The oddball task is traditionally thought of as a non-executive task. The performance of a non-executive task is relatively independent of frontal lobe function. Therefore, brain response during an oddball task would not be expected to show the same magnitude of benefit, as it would during a go-nogo task. As such, there appears to be a degree of specificity in the kind of cognitive function that declines with age.

Advancing age is related to an increase in latency in the P300 as discussed earlier (Beck, Swanson, & Dustman, 1980; Brown, Marsh, & LaRue, 1983). Latency at site F3 was not related to weekly physical activity level, however, at site P4, kilocalorie expenditure was significantly related to P300 latency in the nogo condition of the go-nogo task, indicating that more physically active individuals revealed shorter latencies. This provides additional support for the relationship between executive control processes and physical activity.

There are several possible explanations for the findings in the current study. The participants were high functioning adults residing in an independent living facility. Most of the residents who participated in this research study appeared to be moderately active. Additionally, the sample included mostly men and women with at least an undergraduate degree and several held graduate degrees. Participants' scores on the MMSE indicated that they were high functioning. The mean score on the MMSE for both men and women was 28.62 (sd = 1.58) (MMSE; Folstein, Folstein, & McHugh, 1975). A measure to test IQ was used, the Kaufman Brief Intelligence Test (K-BIT; Kaufman & Kaufman, 1990). It was used to determine the relative intelligence of the participant population for demographic purposes. Participants' mean percentile rank on the K-BIT was 85.67 (sd =

12.96) out of 100. More years of education and higher intelligence may mean that those individuals have less room for cognitive improvement due to physical activity because they are already mentally stimulated and make efforts daily to keep mentally active. In other words, an educated group may have less frontal lobe decline and thus, less potential improvement on executive functioning when they are physically active as related to a more challenged group (dependent living). In this regard the present study provided a rather conservative test of the relationship between physical activity participation and brain function in the elderly.

On a behavioral level, participant's number of errors on the tasks varied, however, participants performed very well on the tasks. The frequency of executive task (nogo) errors made by the participants consisted predominantly of zero, one, or two errors total. The maximum number of total errors an individual made was 26 in the nogo condition. These low frequencies of error imply that the participants were able to inhibit their response, or they were correct in responding. Participants also made only zero, one, or two errors most frequently during the non-executive task (oddball). The maximum number of total errors in the oddball condition for an individual was 43. The EEG level of analysis revealed a different picture than the behavioral but it may be that behavioral differences would emerge if the tasks were sustained over a longer period of time.

Also, in the present study, no reaction time effects were found with physical activity during the oddball task. In addition, no amplitude effects were found. Because of the many factors that affect reaction time beyond P300 latency and amplitude, it is also possible that more sustained behavioral challenges would have revealed differences in reaction time that were related to physical activity level.

In summary, results of the current study are consistent with findings in the literature supporting the notion of an increase in P300 amplitude and decrease in P300 latency with physical activity. Support has been provided for the beneficial effects of physical activity on cognitive function in older adults, specifically related to executive tasks. Many of the participants in the current study reported that they took steps to keep mentally active in addition to their physical activity participation. Cognitive challenges, too, may be beneficial to an aging brain.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

Physical activity appears to have neurobiological benefits. The current study provides support for previous investigations conducted in the last two decades, which have suggested that physical activity may help prevent cognitive decline associated with age. Executive processes, which characterize frontal cognitive processes, are positively related to physical activity in the present sample. The frontal area of the brain declines more rapidly than other areas as we get older (West, 1996). Slowing this decline would make a person's quality of life greater. There are several reasons why the frontal area might be preserved in older persons who engage in physical activity. First, increased oxygen and cerebral blood flow (CBF) occurs during motor behavior (Spirduso, 1980). Second, neurogenesis is promoted through upregulation of brain-derived neurotrophic factor (BDNF) which improves learning and mental function (Cotman & Berchtold, 2002). Additionally, neural structures appear to be maintained in the frontal region in those who are physically active (Colcombe & Kramer, 2003).

The amplitude of the P300 event-related potential was positively related to physical activity in this population, specifically in the left frontal area, which supports the previously stated research. Exploratory analyses revealed that additional support was found in the central region of the brain as well. Support was not found for a relationship (i.e. slope) between age, P300 latency, and physical activity in the nogo trials of a go-nogo task in the frontal area. However additional analyses revealed a relationship in the parietal region for physical activity and age. This indicates that as a person's activity increases, their latency decreases. Additionally, this provides support for the notion that as we age, we process things slower. A positive relationship between P300 amplitude, activity, and the midline parietal region was not supported during the oddball task. As was previously stated, the oddball task is a non-executive task which does not require effortful cognitive processing; therefore the results may indicate that this was an easy task for the participants. A positive relationship in the central region of the brain was found between age and P300 latency, indicating that with an increase in age, latency increases.

Conclusions

The results of the current study revealed:

1. Regular physical activity is beneficial for frontal areas of the brain, particularly for left frontal areas (F3).
2. Additional memory-dependent tasks should be explored relative to cognitive function to provide further support for the beneficial effects of physical activity in an aging population.

Directions for Future Research

Several suggestions for future research follow: A less homogeneous sample of participants, a longitudinal study with event-related potentials for various age groups, several methods of cognitive challenge, and introduction of genetic influences. Additionally, future investigations should explore other possible factors that may influence frontal lobe processes in the elderly other than physical activity, such as genetics, intelligence, education, and nutrition.

Appendix A

Regression analysis of P300 amplitude on age and vigorous exercise: Overall summary of results for amplitudes and latencies elicited at all recording sites during target oddball and nogo trials

Site	Predictor	Nogo P300 Average Amplitude p	Nogo P300 Latency p	Oddball P300 Point Estimate Amplitude p	Oddball P300 Average Amplitude p	Oddball P300 Latency p
FZ	Exercise	0.061	0.669	0.092	0.320	0.749
	Age	0.191	0.243	0.748	0.660	0.637
F3	Exercise	0.032	0.777	0.704	0.463	0.625
	Age	0.211	0.711	0.932	0.750	0.265
F4	Exercise	0.015	0.580	0.261	0.045	0.422
	Age	0.156	0.651	0.733	0.540	0.056
CZ	Exercise	0.065	0.031	0.525	0.036	0.704
	Age	0.189	0.019	0.657	0.930	0.881
C3	Exercise	0.032	0.006	0.308	0.074	0.625
	Age	0.446	0.027	0.517	0.716	0.041
C4	Exercise	0.101	0.290	0.025	0.001	0.727
	Age	0.190	0.107	0.592	0.427	0.581
PZ	Exercise	0.151	0.068	0.247	0.022	0.577
	Age	0.710	0.019	0.761	0.975	0.892
P3	Exercise	0.114	0.009	0.646	0.291	0.925
	Age	0.850	0.026	0.921	0.709	0.493
P4	Exercise	0.118	0.027	0.531	0.137	0.842
	Age	0.550	0.023	0.926	0.958	0.475

Note: No significant results were found between exercise, age, and P300 point estimate amplitudes during nogo trials. As such, they were not reported.

Appendix B

Task Instructions

Oddball Task

For this experiment, you will be seated in this chair listening to tones through the earplugs that are in your ears. You will only need a button to participate in this study.

Once the experiment begins, you will hear a series of tones. Specifically, you will hear two types of tones: low tones and high tones. Your task is to listen to each tone and to respond only to the high tones by pressing the button. For example, if you hear a low tone followed by another low tone, followed by a high tone, you would only respond to the last tone. Try to count the high tones as they are presented, and I will ask you to tell me the number at the end of the task. Please look straight ahead at the target on the wall.

Again, you will hear a series of low and high tones. You are asked to listen to each tone carefully and to only respond to the high tones by pressing the button. Please do not respond to the low tones.

If this isn’t clear right now, don’t worry. I am going to give you some practice tones to get you comfortable with the experiment before we begin.

Lastly, please try to refrain from any excessive movements during the experiment. If you need to scratch, cough, etc. feel free to do so, but if you can hold off until between trials, it would be greatly appreciated.

Do you have any questions before we begin?

Appendix C

Task Instructions

Go-nogo Task

For this experiment, you will be seated in this chair listening to tones through the earplugs that are in your ears. You will only need a button to participate in this study.

Once the experiment begins, you will hear a series of tones. Specifically, you will hear two types of tones: low tones and high tones. Your task is to listen to each tone and to respond only to the low tones by pressing the button. For example, if you hear a low tone followed by another low tone, followed by a high tone, you would only respond to the first two tones. Please look straight ahead at the target on the wall.

Again, you will hear a series of low and high tones. You are asked to listen to each tone carefully and to only respond to the low tones by pressing the button. Please do not respond to the high tones.

If this isn't clear right now, don't worry. I am going to give you some practice tones to get you comfortable with the experiment before we begin.

Lastly, please try to refrain from any excessive movements during the experiment. If you need to scratch, cough, etc. feel free to do so, but if you can hold off until between trials, it would be greatly appreciated.

Do you have any questions before we begin?

Appendix D

The Yale Physical Activity Survey For Older Adults

INTERVIEWER: PLEASE MARK TIME: ______: ______: ______
HR MIN SEC

INTERVIEWER: (Please hand the subject the list of activities while reading this statement.) Here is a list of common types of physical activities. Please tell me which of them you did during a typical week in the last month. Our interest is learning about the types of physical activities that are a part of your regular work and leisure routines.

For each activity you do, please tell me how much time (hours) you spent doing this activity during a typical week. (Hand subject card #1.)

	Time (Hrs/wk)	Intensity Code * (Kcal/min)
Work		
Shopping (e.g., grocery, clothes)	______	3.5
Stair climbing while carrying a load	______	8.5
Laundry (time loading, unloading, hanging, folding only)	______	3.0
Light housework: tidying, dusting, sweeping, collecting trash in home, polishing, indoor gardening, ironing	______	3.0
Heavy housework: vacuuming, mopping, scrubbing floors and walls, moving furniture, boxes, or garbage cans	______	4.5
Food preparation (10+ minutes in duration): chopping, stirring, moving about to get food items, pans	______	2.5
Food service (10+ minutes in duration: setting table, carrying food, serving food	______	2.5
Dish washing (10+ minutes in duration): clearing table, washing/drying dishes, putting dishes away	______	2.5
Light home repair: small appliance repair, light home maintenance/repair	______	3.0

	Time (hrs/wk)	Intensity Code * (Kcal/min)
Heavy home repair: painting, carpentry, washing/polishing car	______	5.5
Other: ____	______	____#
Yardwork		
Gardening: planting, weeding, digging, hoeing	______	4.5
Lawn mowing (walking only)	______	4.5
Clearing walks/driveway: sweeping, shoveling, raking	______	5.0
Other: ______________________________________	______	____#
Caretaking		
Older or disabled person (lifting, pushing wheelchair)	______	5.5
Childcare (lifting, carrying, pushing stroller)	______	4.0
Exercise		
Brisk walking (10+ minutes in duration)	______	6.0
Pool exercises, stretching, yoga	______	3.0
Vigorous calisthenics, aerobics	______	6.0
Cycling, Exercycle	______	6.0
Swimming (laps only)	______	6.0
Other: _____________________________________	______	____#
Recreational Activities		
Leisurely walking (10+ minutes in duration)	______	3.5
Needlework: knitting, sewing, needlepoint, etc.	______	1.5

Dancing (mod/fast): line, ballroom, tap, square, etc.	______	5.5
Bowling, bocci	______	3.0
Golf (walking to each hole only)	______	5.0
Racquet sports: tennis, racquet ball	______	7.0
Billiards	______	2.5
Other: ______________________________________	______	____#

INTERVIEWER: (Please read to subject.) I would now like to ask you about certain types of activities that you have done during the past month. I will ask you about how much vigorous activity, leisurely walking, sitting, standing, and some other things that you usually do.

1. About how many times during the month did you participate in vigorous activities that lasted at least 10 minutes and cause large increases in breathing, heart rate, or leg fatigue or caused you to perspire? (Hand subject card #2)

   Score: 0 = Not at all (go to Q3)
   1 = 1-3 times per month
   2 = 1-2 times per week
   3 = 3-4 times per week
   4 = 5+ times per week
   7 = refused
   8 = don’t know

   Frequency score = __________

2. About how long do you do this vigorous activity(ies) each time? (Hand subject card #3)

   Score: 0 = Not applicable
   1 = 10-30 minutes
   2 = 31-60 minutes
   3 = 60+ minutes
   7 = refused
   8 = don’t know

   Duration score = __________
   weight = 5

VIGOROUS ACTIVITY INDEX SCORE:

FREQ SCORE ____ x DUR SCORE ____ x WEIGHT _____ =__________
(Responses of 7 or 8 are scored as missing.)

3. Think about the walks you have taken during the past month. About how many times per month did you walk for at least 10 minutes or more without stopping which was not strenuous enough to cause large increases in breathing, heart rate, or leg fatigue or cause you to perspire? (Hand subject card #2)

Score:
0 = Not at all (go to Q5)
1 = 1-3 times per month
2 = 1-2 times per week
3 = 3-4 times per week
4 = 5+ times per week
7 = refused
8 = don't know

Frequency score = __________

4. When you did this walking, for how many minutes did you do it? (Hand subject card #3)

Score:
0 = Not applicable
1 = 10-30 minutes
2 = 31-60 minutes
3 = 60+ minutes
7 = refused
8 = don't know

Duration score = __________
weight = 4

LEISURELY WALKING INDEX SCORE:
FREQ SCORE ____ x DUR SCORE ____ x WEIGHT ____ = __________
(Responses of 7 or 8 are scored as missing.)

5. About how many hours a day do you spend moving around on your feet while doing things? Please report only the time that you are <u>actually moving.</u> (Hand subject card #4)

Score:
0 = Not at all
1 = less than 1 hr per day
2 = 1 to less than 3 hrs per day
3 = 3 to less than 5 hrs per day
4 = 5 to less than 7 hrs per day
5 = 7+ hrs per day
7 = refused

8 = don’t know Moving score = ___________
weight = 3

MOVING INDEX SCORE:
FREQ SCORE ____ x WEIGHT ____ = ___________
(Responses of 7 or 8 are scored as missing.)

6. Think about how much time you spend standing or moving around on your feet on an average day during the past month. About how many hours per day do you stand? (Hand subject card #4)

Score:
0 = Not at all
1 = less than 1 hr per day
2 = 1 to less than 3 hrs per day
3 = 3 to less than 5 hrs per day
4 = 5 to less than 7 hrs per day
5 = 7+ hrs per day
7 = refused
8 = don’t know Standing score = ___________
weight = 2

STANDING INDEX SCORE:
FREQ SCORE ____ x WEIGHT ____ = ___________
(Responses of 7 or 8 are scored as missing.)

7. About how many hours did you spend sitting on an average day during the past month? (Hand subject card #5)

Score:
0 = Not at all
1 = less than 3 hours
2 = 3 hrs to less than 6 hrs
3 = 6 hrs to less than 8 hrs
4 = 8+ hrs
7 = refused
8 = don’t know Sitting score = ___________
weight = 1

SITTING INDEX SCORE:
FREQ SCORE ____ x WEIGHT ____ = ___________
(Responses of 7 or 8 are scored as missing.)

8. About how many flights of stairs do you climb up each day? (Let 10 steps = 1 flight.)

____

9. Please compare the amount of physical activity that you do during other seasons of the year with the amount you just reported for a typical week in the past month. For example, in the summer, do you do more or less activity than what you reported doing in the past month? (INTERVIEWER: PLEASE CIRCLE THE APPROPRIATE SCORE FOR EACH SEASON.)

	Lot More	Little More	Same	Little Less	Lot Less	Don't know
Spring	1.30	1.15	1.0	0.85	0.70	--
Summer	1.30	1.15	1.0	0.85	0.70	--
Fall	1.30	1.15	1.0	0.85	0.70	--
Winter	1.30	1.15	1.0	0.85	0.70	--

SEASONAL ADJUSTMENT SCORE = SUM OVER ALL SEASONS/ 4 _________

INTERVIEWER: PLEASE MARK TIME: ______: ______: ______
HR MIN SEC

Card #1
Weekly Physical Activities

Work

Shopping (e.g., grocery, clothes)

Stair Climbing while carrying a load

Laundry

Light Housework:	tidying, dusting, sweeping, collecting garbage in home, polishing, indoor gardening, ironing
Heavy Housework:	vacuuming, mopping, scrubbing floors and walls, moving furniture, moving boxes or garbage cans
Food preparation (+10 min.):	chopping, stirring, moving around to get food items, pots or pans
Food service (+10 min.):	setting table, carrying food, serving food
Dish washing (+10 min.):	clearing table, washing and drying dishes, putting dishes away
Light home repair:	small appliance repair, light household maintenance and repair tasks
Heavy home repair:	painting, washing and polishing car, carpentry
Other:	______________________________

Yardwork

Gardening:	pruning, planting, weeding, hoeing, digging
Lawn mowing (walking only)	
Clearing walks and driveway:	raking, shoveling, sweeping
Other:	______________________________

Caretaking

Older or disabled person:	lifting, pushing wheelchair
Childcare:	lifting, pushing stroller

Exercise

Brisk walking for exercise (10 + min.):	causes large increases in heart rate, breathing or leg fatigue
Stretching exercises, yoga, pool exercise	
Vigorous calisthenics, aerobics:	causes large increases in heart rate, breathing or leg fatigue
Cycling, exercycle	
Lap swimming	
Other:	______________________________

Recreational Activities

Leisurely walking (10+ min.)	
Hiking	
Needlework:	knitting, sewing, crocheting, needlepoint
Dancing (mod/fast):	line dancing, ballroom, square, tap, etc.
Bowling, bocci	
Golf (walking each hole only)	
Racquet sports:	tennis, racquetball
Other:	______________________________

Card #2

Not at all
1-3 times per month
1-2 times per week
3-4 times per week
5 or more times per week
Don’t know

Card #3

10-30 minutes
31-60 minutes
60 or more minutes
Don’t know

Card #4

Not at all
Less than 1 hour per day
1 to less than 3 hours per day
3 to less than 5 hours per day
5 to less than 7 hours per day
7 or more hours per day
Don’t know

Card #5

Not at all
Less than 3 hours per day
3 to less than 6 hours per day
6 to less than 8 hours per day
8 or more hours per day
Don’t know

Appendix E

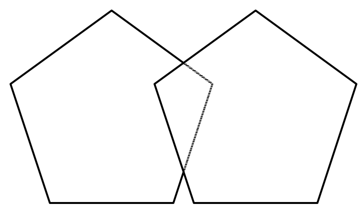
Mini-Mental State Examination (MMSE)

Date ____________________
Patient's Name _______________________
Examiner's Name _____________________

Maximum Score	**Score**	**ORIENTATION**
5	( )	What is the (year) (season) (date) (day) (month)?
5	( )	Where are we: (state) (county) (town or city) (hospital) (floor)?
3	( )	**REGISTRATION** Name 3 common objects (eg, "apple, table, penny"): Take 1 second to say each. Then ask the patient to repeat all 3 after you have said them. Give 1 point for each correct answer. Then repeat them until he/she learns all 3. Count trials and record. Trials:
5	( )	**ATTENTION AND CALCULATION** Serial 7's backwards. Give 1 point for each correct answer. Stop after 5 answers. Alternatively, spell "WORLD" backwards. One point for each correct letter.
3	( )	**RECALL** Ask for the 3 objects repeated above. Give 1 point for each correct answer (Note: Recall cannot be tested if all 3 objects were not remembered during registration.)
		LANGUAGE
2	( )	Name a "pencil," and "watch."
1	( )	Repeat the following: "No ifs, ands, or buts."
3	( )	Follow a 3-stage command: "Take a paper in your right hand, fold it in half, and put it on the floor."
1	( )	Read and obey the following:

Close your eyes.

1	( )	Write a sentence.
1	( )	Copy the following design:



Total Score __________

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