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EVALUATION OF TRANSIENT COGNITIVE CHANGES FROM MAXIMAL EXERTION AND RESPIRATOR WEAR

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EVALUATION OF TRANSIENT COGNITIVE CHANGES

FROM

MAXIMAL EXERTION AND RESPIRATOR WEAR

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Dissertation

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Evaluation of Transient Cognitive Changes from Maximal Exertion and Respirator Wear

Chairperson: Darrell Stolle, Ed.D.

A comprehensive occupational respiratory protection program is mandated by federal law to protect workers exposed to breathing hazardous atmospheres. Those wearing respirators and/or performing high-intensity physical work may endure physiological and/or psychological impairment from cardiorespiratory stress, respirator anxiety, and working in hazardous conditions. The effects of multiple stressors may impede or override physiological and psychological adaptation mechanisms, causing cognitive deterioration or disruption when clarity and speed of thought and action are crucial.

This study examined transient cognitive differences due to activity, respirator, and gender wear through examination of archival data collected during two studies that evaluated the physiological effects of activity and respirator wear. Scores and response times from the Mini Mental State Examination (MMSE), a brief verbally administered assessment of cognitive function, were collected and archived in anticipation of developing this line of research. The sample of 18 active healthy college students (9 males and 9 females) performed the Wingate Anaerobic Test (WAnT), a cycle ergometry protocol requiring subjects to pedal as fast as possible for 30 seconds against a prescribed resistance. Subjects performed four discrete treatments—three immediately post-WAnT and one at rest. The MMSE was administered immediately after performance of the WAnT wearing no respirator (N), wearing a half face air-purifying respirator (P), and wearing a half face air-supplying respirator (S); and with the subject seated wearing no respirator (R). For each MMSE administration, the total and 11 sectional scores and response times were recorded for the required questions and tasks.

A Minitab two-way ANOVA was performed on the total and sectional MMSE scores and times. Where treatment proved significant, Bonferroni 95% Confidence Intervals were calculated to identify important treatment comparisons. Statistically reliable differences ($p < .05$) in total and select sectional scores and times relative to activity level, respirator usage, gender, and individual subject response variance were identified. Scores were assumed to represent thought clarity and times to represent response speed. It was concluded that cognitive function regarding thought clarity and response speed differs selectively from changes in activity level without respirator wear, respirator usage after maximal exertion, gender, and individual subject response variance.

DEDICATION

This document and the effort devoted to its completion are dedicated to God and to my family, who have nourished me at all times and in all ways. Their understanding, forgiveness, support, and loyalty inspire and sustain me.

Dear Mom and Dad, Evan and Virginia Martinsen, provided a foundation of security, unconditional love, acceptance, and support that never wavered. These words are here because of Dad's encouragement to use my brain.

My grandparents, Josephine and John Dougherty (Nana and Bop) and Mathea Martinsen (Grandma) gave me the pleasure of having, and showed me the art of being, a stellar grandparent.

My sisters, Sandy Kieckbusch (Sindie) and Susan Harrington (Sus'n), dearest friends, and role models, taught their shy, insecure, admiring little sis how to be gracious, loving, fun, and strong with a smile. My dear brothers-in-law, Larry Kieckbusch and Len Harrington, put up with me and finally (I think) came to like me!

My once husband and always friend, Scott Bardsley, loved and supported our sons and me through good and bad, and left us too soon to fulfill his own academic and other dreams.

My son, John Bardsley, once my intense and inquisitive little boy, is now my astute friend, valued advisor, and an outstanding man, husband, father, and scholar.

My son, Kadin Bardsley, once my unassuming, quietly talented little boy, is now a fine man of the same ilk whose discernment, abilities, strength and loyalty run strong, silent, and deep.

My daughter-in-law, Jennifer Racicot Bardsley, has infused our stoic family with beauty and exuberance and taught us to show love, embrace life, and see the bright side!

My dear grandchildren, Alex and Ellie Bardsley, lighten my heart, brighten my life with their wonder and promise, and make me look forward to the future.

The steadfast devotion of my dog Chug, dear departed friend and companion, kept my heart open and my sanity intact through anguish, exhilaration, and everything in between. No further explanation is necessary or sufficient.

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Montana Tech and The University of Montana have given me my undergraduate and graduate education, my livelihood, and financial support in completing this degree. I am proud to be a graduate and employee of Montana Tech, and proud (and relieved) to finally be a UM graduate. As a UM freshman in 1968, I had no idea it would take so long!

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CHAPTER ONE

STATEMENT OF THE PROBLEM

Introduction

Upon congressional enactment of the Occupational Safety and Health Act of 1970, the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) were created and worker safety and health became a mandate for most private sector employers. In the United States and select territories, the majority of workers in the wide array of occupations and workplaces are protected by the safety and health regulations promulgated and enforced by OSHA, an agency within the Department of Labor. OSHA standards are often based on research, information, and recommendations provided by NIOSH, the federal agency housed in the Centers for Disease Control that is responsible for occupational safety and health research. The standards address a broad range of occupational safety and health hazards and exposure control methods. Respiratory protection is an important mode of hazard control for workers potentially exposed to breathing hazardous atmospheres, and is regulated by the OSHA Respiratory Protection Standard (Occupational Safety and Health Administration [OSHA], 2008).

An estimated five million workers in over a million workplaces in the United States are required to wear respirators for protection from breathing air that is oxygen-deficient and/or contaminated with chemicals that can cause acute or chronic disease, impairment, or death (Occupational Safety and Health Administration [OSHA], n.d.). Donning a respirator is the least desirable control method for hazardous atmospheres because the hazard itself still exists and the only intercession between the worker and the hazard is the respirator, which is not invincible. In addition, respirator wear can be stressful due to the associated physiological and psychological effects. Medical determination of worker ability to tolerate the additional strain of a respirator should include assessment of physical fitness, health, work characteristics, and the type and requirements of the respirator to be used (Szeinuk, Beckett, Clark, & Hailoo, 2000). Yet few organizations that require workers to wear respirators have physical fitness or work capacity standards for their workers (Sharkey & Davis, 2008).

Although properly selected and worn respirators shield workers from inhaling hazardous atmospheres, they also increase the work of breathing (WOB) (Coyne, Caretti, Johnson, Scott, & Koh, 2006) and may cause anxiety (Caretti, 1997), both from the respirator itself and from being in a potentially hazardous atmosphere or situation. In addition, intense physical activity in a respirator may critically overload the worker's capabilities (Akbar-Khanzadeh, Bisesi, & Rivas, 1995). If intense physical activity can also cause temporary decreases in cognition (Tomporowski, 2003), how does respirator wear during intense physical exertion affect cognition? Investigation of these interactions is of interest to the research, occupational, and regulatory communities.

The OSHA Respiratory Protection Standard, 29 CFR 1910.134, outlines the legal requirements for employers whose workers are required to wear respirators. The requirements of the standard include a written program, respirator selection and use, fit testing, and medical evaluation for workers that wear a respirator (OSHA, 2008). OSHA acknowledges that respirator wear may impose a physiological burden depending on type of respirator, the job and workplace conditions, and the medical status of the employee. The minimum mandatory medical evaluation required by the standard for workers who will wear a respirator consists of employee completion of the OSHA Respirator Medical Evaluation Questionnaire (see Appendix A), a self-administered and self-reporting document that is submitted by the employee, but not necessarily in person, to a physician or licensed health care professional (PLHCP) for review (OSHA, 1998).

The worker is approved to wear a respirator if, after review of the questionnaire, the PLHCP identifies no issues regarding respirator wear and no need for medical examination. Even though face-to-face medical determination of worker toleration of respirator wear is recommended, (Szeinuk, Beckett, Clark, & Hailoo, 2000; Sharkey & Davis, 2008), an in-person medical examination is required only if the PLHCP deems it necessary. Due to the cursory and subjective nature of this medical screening procedure, potentially critical health issues could be overlooked, particularly if the worker is not truthful, accurate, or comprehensive in the self-assessment.

In the questionnaire, the psychological aspects of respiratory wear are addressed with one question asking workers that have previously worn respirators whether they have had respirator anxiety. There is no other inquiry related to mental or psychological aspects of respirator wear, although NIOSH recommends that approval to wear a respirator include a medical history, a physical exam, and physician assessment as to whether respirator wear would cause anxiety or claustrophobia (Bollinger, 2004). Caretti (1997) found that prolonged respirator wear at rest significantly increased anxiety even when no adverse cognitive effects were seen. Anxiety can activate physiological, behavioral, and verbal-cognitive response systems (Eysenck, 1992) that could in turn disrupt both overt and covert reactions, adaptations, and compensations involved in maintenance of physiological and psychological equilibrium.

Work capacity is to the ability of a person to perform as needed without undue fatigue or becoming a hazard to self or others. Physically demanding tasks require high energy expenditure, and even though engineering and technology have reduced the magnitude of physical labor once inherent in most work tasks, there is still a variety of physically rigorous occupations such as public safety, emergency response, mining and construction in which respirator wear is often necessary. Studies have shown that emergency service personnel have poor physical fitness (Sharkey & Davis, 2008). Evaluation of worker physical capabilities and reactions while wearing a respirator in non-threatening conditions would inform both management and the worker of possible problems before occurrence of a critical incident.

NIOSH and others propose that respirator wearers be pre-screened by a physician in consideration of health, the work conditions, and the respirator to be worn (Hodous, Boyles, & Hankinson, 1986; Sharkey & Davis, 2008), and that approval to wear a respirator include an exertion component both with and without respirator wear to evaluate heart rate response (Harber, Tamimie, Emory, Bhattacharya, & Barber, 1984). Although employees completing the questionnaire are asked to estimate work effort intensity and duration while wearing a respirator, no questions address their general physical activity habits or physical fitness and no formal assessment of physical fitness is conducted. Assessment of workers' physical fitness and work capacity in a respirator would allow determination of their respirator-mediated limits. One index of both work intensity and the functional capacity of the cardiorespiratory system is oxygen consumption—the volume of oxygen that is required or utilized for performance of a given activity.

When at rest or during performance of activities of low or moderate intensity, the human body is sustained by aerobic or oxygen-using metabolic processes. Most normal life and work activities are aerobic and involve submaximal effort that can be sustained over time depending on the individual's capabilities and the activity intensity. For activities that require immediate high-intensity effort, however, the body's ability to utilize oxygen can be overcome (Inbar, Bar-Or, & Skinner, 1996). As work intensity increases to maximal or near-maximal levels, there is a shift from predominantly aerobic to predominantly anaerobic metabolism in which cellular oxygen demand exceeds the body’s ability to supply. Anaerobic activity cannot be sustained more than a few minutes at most due to its extreme intensity and the accompanying lack of adequate oxygen supply (Powers & Howley, 2007; Sharkey & Davis, 2008). Anaerobic activities that can occur in both every day and occupational activities include sprinting, running up stairs, and moving heavy objects. Aerobic and anaerobic capacities vary among individuals and are related to health and physical fitness.

Firefighting and emergency response are examples of occupations in which performance of a variety of aerobic and anaerobic activities while wearing respirators is likely. A study of firefighter work intensity and respirator wear conducted during a firefighting exercise found that exertion stabilized at 90-100% of the estimated maximum exertion level regardless of respirator type (Manning, Griggs, & Thomas, 1983). Exertion of this intensity is extremely demanding on the cardiorespiratory system. Indeed, for any occupation that is physically rigorous, especially if other stressors like respirator wear or temperature extremes are present, a minimum level of worker fitness should be required.

Overall health and physical fitness influence performance quantity and quality and a person’s ability to adapt to and endure physiological stress, which in turn affects their mental state. Less physically fit individuals generally reach their maximum work capacity more quickly and at lower work intensities than fit persons (Powers & Howley, 2007). Those with low levels of fitness can only intermittently perform extremely heavy work that exceeds their aerobic capacity (Sharkey & Davis, 2008). A submaximal aerobic activity performed easily by a healthy, physically fit person may be exhaustive and anaerobic for someone less fit. Further, a submaximal task easily completed by a person unimpeded by extraneous stressors such as respirator wear, anxiety, or high temperatures may deplete and overburden that same person in more physiologically and/or psychologically demanding conditions.

In addition to work task demands, respirator wear increases oxygen consumption (Zimmerman, Eberts, Salvendy, & McCabe, 1991) and the overall physiological strain on the respiratory and other body systems due to increased breathing resistance (Coyne et al., 2006). Because protective clothing and respirator wear pose potentially dangerous thermoregulatory and cardiorespiratory stress regardless of workload intensity or external conditions (White, Vercruyssen, & Hodous,1989), assessment of cardiorespiratory fitness should be considered for workers required to wear respirators, particularly if high intensity workloads are possible (Northington, Suyama, Goss, Randall, Gallagher, & Hostler, 2007; Hodous, 1986). Although properly selected and fitted respirators safeguard the wearer, the resulting increase in physiological and psychological discomfort and effects may reach critical levels if the rigor of the physical demands approaches the worker's maximum work capacity (Akbar-Khanzadeh, Bisesi, & Rivas, 1995). Because respirators impede work performance due to increased breathing resistance, increased dead space, respirator weight, and psychological factors, sufficient physical work capacity for the combined rigors of the task and respirator is essential for worker health and safety (Sharkey & Davis, 2008).

Thus, when assessing physiological responses or performance limitations during respirator wear, multiple stressors must be considered. However, the magnitude of individual and combined responses cannot be predicted (Babb, Turner, Saupe, & Pawelczyk, 1989). The combination of arduous physical requirements, hazardous conditions, and respirator wear may initiate and exacerbate physiological and psychological effects, overtax adaptation mechanisms, and contribute to a critical physical or mental overload and even breakdown. At a time when it is essential to be physically and mentally astute and able to act quickly and think clearly, the worker may instead be physiologically and/or cognitively precarious.

Cognition or cognitive function is an abstract concept associated with thinking ability and can be regarded and measured either as a whole or as the combination of various individual abilities such as memory, attention, language, planning, and reaction time (Folstein, Folstein, & Fanjiang, 2001). The definition of cognition varies among experts. Bloom (1956) defined the cognitive learning domain as recall and recognition of knowledge and intellectual development. Bloom’s cognitive domain categories, from simplest to most complex, are knowledge, comprehension, application, analysis, synthesis, and evaluation (Bloom, 1956). Anderson and Krathwohl (2001) revised these to include remembering, understanding, applying, analyzing, evaluating, and creating. Psychomotor abilities, too, are included in the realm of cognition (Carroll, 1993).

According to Carroll (1993) cognitive ability is the capacity to successfully perform cognitive tasks that require correct or appropriate processing of mental information, and the main cognitive abilities are language, reason, memory and learning, visual perception, auditory reception, idea production, cognitive speed, knowledge and achievement, and psychomotor abilities. Rather than a static trait, Carroll considers cognitive ability to be a kind of potential that may vary not only across individuals but within one individual.

The application and implications of cognitive processes and consequences cannot be compartmentalized but must be considered as an integrated and dynamic feedback loop that includes and is influenced by physiological, affective, and psychomotor considerations. In a broad sense, any consciously performed task is a cognitive task that involves thinking, feeling, and doing. Cognitive function encompasses a class of tasks comprised of a collection of attributes that, while their specific parameters may vary, require the same or similar abilities. Thus, to fully describe such a multifaceted attribute would require a summative assessment across the spectrum of these similar and related capabilities (Carroll, 1993).

The Mini Mental State Examination (MMSE), the cognitive function evaluation instrument used in this research, is one such assessment. Its creators, Folstein, Folstein, and McHugh (1975), also contend that cognitive ability involves mental alertness and information processing in various areas, some of which overlap into physiological realms, such as reaction time and other psychomotor skills. The components of the MMSE reflect this comprehensive view of cognition. There are 11 sections of the MMSE, each focusing on a particular facet of cognitive and psychomotor function. Each is scored separately and all are combined into a summary score meant to be an index of cognitive status at the time of the assessment (Folstein, Folstein, & McHugh, 1975). Cognitive status is a variable, not a constant, in the human equation. It can be affected by a variety of intrinsic and extrinsic factors, one being physical activity.

The effects of both acute and chronic physical exercise on cognitive function have been widely investigated. However, contradictory findings and selective effects that vary with the psychological task and the mode, intensity, and duration of the activity indicate the need for further studies (Brisswalter, Collardeau, & Rene, 2002). Fleury and Bard (1987) concluded that while peripheral vision improved from various exercise intensities, cognitive behavior was impaired by maximal effort activities. Hancock and McNaughton (1986) found significantly impaired ability to perceive visual information in subjects exercising at or above their anaerobic threshold. Tomorowski (2003) concluded that some aspects of information processing are improved in short term submaximal aerobic exercise, that information processing and memory were impeded during extended exercise, and that intense anaerobic exercise produced a small transitory decreases in cognition.

Others found a positive effect of exercise on cognition as a function of fitness level, a chronic exercise program, and acute exercise (Etnier, Salazar, Landers, Petruzzello, Han, & Nowell, 1997). Although their meta-analysis examining the relationship between aerobic fitness and cognitive performance showed no significant relationship, Etnier, Nowell, Landers, and Sibley (2006) suggested further research on both the dose-response relationship between aerobic fitness and cognitive performance and other physiological and psychological influences that could affect the relationship between physical activity and cognitive performance. One such influence is wearing a respirator.

Those that have worn a respirator acknowledge the discomfort of doing so. The observed effects of respirator wear include increased oxygen consumption (Wilson & Raven, 1989), decreased work performance time to exhaustion (Wilson, Raven, Morgan, Zinkgraf, & Jackson, 1989), and anxiety (Johnson, Dooly, Blanchard & Brown, 1995). Cognition can be variously altered by respirator wear, activity, and the combination of both, but the evidence cannot be collated into solid substantiation of explicit effect, magnitude, or direction over the range of activity levels, respirators, and types of cognitive assessments (Etnier et al., 2006).

Problem Statement

Respirator wear and hard physical labor, both individually and in combination, are common in many work environments. Ideally, every worker required to perform hard physical work wearing a respirator would be thoroughly screened for the ability to do so without adverse physiological or psychological stress or ramifications. The OSHA respiratory protection standard requires workers that wear respirators to be medically cleared through self-completion of a questionnaire that is reviewed by a medical professional. No face-to-face interaction or evaluation of ability to wear a respirator and perform hard work is required. Adverse effects from either or both of these stressors may impair the worker's ability to think clearly and act quickly and lead to serious consequences. Re-evaluation and renovation of existing federal regulation of respirator wear with regard to worker health and fitness, work intensity, and respirator selection will insure that workers wearing a respirator are aware of and can safely endure the accompanying physiological and psychological stress of hard work while wearing a respirator.

Prior studies about the cognitive effects of activity, of respirator wear, and of the two combined encompass an assortment of research designs and have yielded inconsistent and even contradictory results from which firm conclusions cannot be drawn. Further research is needed to address overall and gender-specific cognitive changes from maximal exertion or respirator wear, individually and in combination. This study has expanded upon and addressed gaps in the existing research, and may also initiate reconsideration and renovation of federal regulation of respirator wear with regard to worker health and fitness, work intensity, and respirator wear and selection. The results of this and other similar research demonstrate the need to strengthen the respirator screening and worker fitness requirements to insure that workers wearing respirators are ready and able for the physiological and psychological rigors of the work

Purpose of the Study

Task performance and cognition dovetail such that what affects one will likely also impact the other (Carroll, 1993). The mode and degree of response depend on the affected physiological and cognitive realms and the nature of the cause. Task intensity and respirator wear are two possible influences on cognition and task performance in the workplace. Workers required to wear respirator should be scrutinized for both ability to perform the task and to use the equipment (Sharkey & Davis, 2008). If a task is critical and/or performed in a perilous environment, knowing the effects of such influences is important to ensure both proper and safe task performance and the safety and health of other workers and the environment.

The purposes of this study were to identify important overall and gender-related differences in cognitive ability that arise from short term maximal exertion with or without respirator wear and to compare differences in cognition between two types of respirator. In general, females have lower lung function, muscular strength, and functional capacity—all factors in work performance and respirator wear (Sharkey & Davis, 2008). Unfavorable changes or differences attributed to respirator or gender would support the need to more stringently pre-screen respirator wearers for health and fitness and perhaps institute periodic physiological assessments and rest breaks for respirator wearers doing heavy work. Important differences between respirators and/or between genders are important regarding respirator selection and task limitations for vulnerable workers.

Research Questions

In order to more comprehensively describe transient cognitive differences that occur as a result of activity level, respirator usage, and gender, the total and 11 sectional MMSE scores and times were analyzed for statistically reliable differences ($p < .05$) with regard to activity, respirator usage, and gender. The following five research questions were explored through testing of ten related null hypotheses.

Research Question 1 – Activity Effects

Will the cognitive function of healthy, active college students vary significantly due to activity level differences?

Research Question 2 – Respirator Wear Effects

Will the cognitive function of healthy, active college students measured after maximal exertion vary significantly due to respirator usage differences?

Research Question 3 – Gender Differences

Will the cognitive function of healthy, active college males and females differ significantly from one another due to activity level or respirator usage differences?

Research Question 4 – Interactive Effects

Will the cognitive function of healthy, active college students vary significantly due to the interaction of treatment (activity intensity, respirator usage) and gender?

Research Question 5 – Individual Subject Response Variance

Will there be significant variance in cognitive function measurements due to individual subject response differences?

Transient cognitive impairment was assumed with statistically reliable decreased/lower MMSE scores and increased/faster MMSE times. Cognitive improvement was assumed with a statistically reliable increase in MMSE scores and decrease in MMSE times. The term ‘treatment’ includes elements of activity (resting or post-maximal exertion) and respirator wear (no respirator, air-purifying respirator, or air-supplying respirator).

Hypotheses

Inherent to the inclusive nature of the hypotheses as stated was testing of the individual relationships between and among the predictor or independent variables and response or dependent variables. The predictor variables are treatment, gender, and individual subject response. The response variables are the total and sectional MMSE scores and times. There are 12 score variables and 12 time variables. Statistical reliability was set below an alpha level of .05 (*p* <. 05). The following research or alternative (H_a) and null (H_0) hypotheses were posed.

- H_a 1. Activity differences will produce a statistically reliable effect on total or sectional MMSE scores.
  - H_0 1. Activity differences will not produce a statistically reliable effect on total or sectional MMSE scores.
- H_a 2. Activity differences will produce a statistically reliable effect on total or sectional MMSE times.

  - H_0 2. Activity differences will not produce a statistically reliable effect on total or sectional MMSE times.
- H_a 3. Respirator usage differences will produce a statistically reliable effect on total or sectional MMSE scores.
  - H_0 3. Respirator usage differences will not produce a statistically reliable effect on total or sectional MMSE scores.
- H_a 4. Respirator usage differences will produce a statistically reliable effect on total or sectional MMSE times.
  - H_0 4. Respirator usage differences will not produce a statistically reliable effect on total or sectional MMSE times.
- H_a 5. Gender differences will produce a statistically reliable effect on total or sectional MMSE scores.
  - H_0 5. Gender differences will not produce a statistically reliable effect on total or sectional MMSE scores.
- H_a 6. Gender differences will produce a statistically reliable effect on total or sectional MMSE times.
  - H_0 6. Gender differences will not produce a statistically reliable effect on total or sectional MMSE times.
- H_a 7. Gender and treatment in interaction will produce a statistically reliable effect on total or sectional MMSE scores.
  - H_0 7. Gender and treatment in interaction will not produce a statistically reliable effect on total or sectional MMSE scores.
- H_a 8. Gender and treatment in interaction will produce a statistically reliable effect on total or sectional MMSE times.

    - H_0 8. Gender and treatment in interaction will not produce a statistically reliable effect on total or sectional MMSE times.
- H_a 9. Variance in individual subject response measurements will produce a statistically reliable effect on total or sectional MMSE scores.
    - H_0 9. Variance in individual subject response measurements will not produce a statistically reliable effect on total or sectional MMSE scores.
- H_a 10. Variance in individual subject response measurements will produce a statistically reliable effect on total or sectional MMSE times.
    - H_0 10. Variance in individual subject response measurements will not produce a statistically reliable effect on total or sectional MMSE scores.

Importance of the Study

Federal law governing whether a worker is fit to wear a respirator is currently based primarily on a self-reporting questionnaire and does not require examination by a medical professional or objective or quantitative assessment of physical or psychological well being. Should this study reveal important transient cognitive differences from maximal physical activity and respirator wear, this information can be considered in developing more comprehensive respirator regulations, programs, and practice that will result in improved protection for the millions of workers required to wear respirators in occupational environments. Although healthy active college students do not represent a sample of the real world working population, reflection on changes seen in this sample may be of vital importance when considering an older, less healthy, more sedentary work force.

In addition to documenting differences between females and males, this study may also identify possible differences in cognitive response between two respirators with different face mask pressures, a consideration in assessing the work of breathing (WOB). Greater WOB translates to more physiological strain which in turn may affect cognitive ability. Significant differences due to respirator type or gender would indicate the need to consider a respirator wearer's health and capabilities concerning respirator wear and selection, in addition to task intensity considerations.

The results of this research have implications in several areas. They are important to employers that require employees to wear respirators and to safety and health professionals that must select proper respiratory protection. They are also important to agencies such as OSHA whose mission is to ensure worker health and safety and to promulgate and enforce standards that support that mission. Finally, they are important to anyone that may be required to perform hard work wearing a respirator in a potentially hazardous atmosphere. These people should be educated about the limitations, physiological and cognitive effects, and signs and symptoms of intense activity, both alone and in tandem with respirator wear.

Definitions of Key Terms

For this research the following terms and corresponding definitions apply:

Aerobic means with oxygen. Aerobic physical activity is of a low enough (submaximal) intensity that inhaled oxygen is adequately supplied to metabolize adenosine triphosphate (ATP), the energy substrate that fuels body processes including movement. Aerobic activities can be sustained over time (Powers & Howley, 2007). Walking and jogging are aerobic activities. In this study, the cycle ergometer warm-up, sprint recovery, and cool-down were aerobic activities.

Air-purifying respirators are tight-fitting respirators into which inhaled air is drawn through a filtering mechanism that captures airborne contaminants before entering the mask and the respiratory system. They contain an air-purifying filter, cartridge, or canister that removes specific air contaminants by passing ambient air through the air-purifying element. Air-purifying respirators can have either negative or positive facemask pressure on inhalation. In this research, half face 3M negative pressure air-purifying respirators with high efficiency filters were used for the P treatment.

Air-supplying respirators, also called supplied air or airline respirators, are atmosphere-supplying respirators that supply breathing air through an airline connected to a clean air source independent of the ambient atmosphere. These respirators might be used in hazardous atmospheres in which an air-purifying respirator will not provide adequate protection. In this research, half face 3M respirators connected to an air compressor that supplied air into the mask at 150 liters per minute were used for the S treatment.

Anaerobic means without oxygen. Anaerobic activity is of a high enough (maximal or nearly maximal) intensity that sufficient oxygen cannot be supplied to aerobically sustain ATP metabolism to fuel the activity. The duration of anaerobic activity can vary from a few seconds to a few minutes (Powers & Howley, 2007), after which performance of the activity is self-limited by the lack of sufficient cellular oxygen. The 100 yard dash is an anaerobic activity. In this study, anaerobic activity was generated during the Wingate Anaerobic Test (WAnT) cycle ergometer protocol that comprised the activity component of the treatments.

Cognition refers to mental information processing with regard to the following areas: orientation to time and place, registration, attention, calculation, recall, naming, repetition, comprehension, reading, writing, and drawing (Folstein, Folstein, &

Fanjiang, 2001). In this study, cognition was assessed using Mini Mental State Examination (MMSE) scores and times, both total and per individual section.

Cognitive ability or function is the capacity to perform cognitive tasks for which successful performance requires correct or appropriate processing of mental information (Carroll, 1993).

The Mini Mental State Examination (MMSE) is a brief assessment of cognitive function comprised of 11 sections containing a variety of questions to answer and tasks to perform. In this research, the MMSE was administered for each treatment and scores and times from each MMSE administration are the data for this study.

Negative pressure tight fitting respirators have negative (inward or suction) pressure generated inside the mask during inhalation and positive (outward) pressure generated inside the mask upon exhalation due to the airtight seal between the respirator and the wearer's face. For the P treatment subjects wore tight-fitting 3M negative pressure half face respirators with N-95 particulate filters attached.

A physician or other licensed health care professional (PLHCP) is an individual whose legal scope of practice includes provision of or responsibility for the health care services required by the OSHA respiratory protection standard.

Positive pressure respirators can be either tight-fitting or loose-fitting and have positive (outward) pressure inside the facepiece that exceeds the ambient air pressure outside the respirator during both inhalation and exhalation. For the S treatment subjects wore 3M half face respirators connected to an airline and compressor that supplied air into the mask, providing positive pressure inside the mask.

Respirators are devices attached to the face or head that provide the wearer with protection from inhaling hazardous atmospheres. For this research, 3M half-face tight-fitting respirators were use for both respirator treatments.

Tight-fitting respirators form an airtight seal with the face, and protection is based on the seal remaining intact to prevent entry of atmospheric air into the respirator through any other route than the inhalation valves. For this research, in both respirator treatments, subjects wore tight-fitting 3M negative pressure half face respirators.

Treatment refers to one of four sessions that each research subject performed. In this study, each treatment was comprised of both an activity element and a respirator usage element. The activity elements were seated at rest or performance of the Wingate Anaerobic Test (WAnT), and the respirator usage elements involved wearing no respirator, an air-purifying respirator, or an air-supplying respirator.

The Wingate Anaerobic Test (WAnT) is an anaerobic cycling protocol that involves pedaling a stationary cycle ergometer as hard and fast as possible for 30 seconds at a prescribed resistance based on the subject's weight. A cycle ergometer allows precise workload quantification.

Summary of Chapter One

When considering the importance of worker health and safety, the current respiratory protection screening requirements, the observed physiological and psychological effects of activity and respirator wear, and the diversity of and gaps and deficiencies in the research collating these areas, the need for more research is evident. There is always a need to broaden and deepen the knowledge base to answer existing questions and generate new questions. The synthesis of old and new knowledge about physical activity, respirator wear and cognition will both enrich a burgeoning line of research and contribute to worker safety and health. If this information translates into real-world application through strengthened regulation of workplace respirator wear, one purpose of this study will be fulfilled.

Chapter Two is Review of Related Literature that reports, develops, compares, and contrasts current knowledge and research about physical activity, respirator wear, and cognition as related to the research questions. This review provides a cohesive account of known facts and research results that will inform, connect, and define gaps and contradictions in the literature. In so doing, the need for and value of answering the questions asked in this study will emerge.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Introduction

Assorted studies have investigated respirator wear, physical activity, and cognition but their results are difficult to generalize due to the incongruent research designs. The complex matrix of respirator types, activity modes and intensities, and cognitive domains and assessments present a challenge to finding consensus. This review of related literature will provide the reader with fundamental knowledge upon which to base an understanding and critique of related studies and often contradictory findings. The following areas pertinent to this study will be reviewed.

1. The Brain and Exercise
2. Cognition and Exercise
3. Physiological Effects of Respirator Wear
4. Respirator Wear, Cognition, and Exercise
5. Gender Differences, Cognition, and Exercise

The Brain and Exercise

The premise that exercise starts and ends in the brain can be extended to include cognition and, indeed, most facets of life. The brain is the command center or “central governor” of the human organism, and voluntary exercise begins and ends with a conscious decision (Kayser, 2003). The connection between the brain and exercise can be interpreted behaviorally, physiologically, or psychophysiologically (Etnier & Landers, 1995). Advances in understanding and mapping brain function continue but many mysteries remain, including the intricacies of cerebral control and interaction as related to exercise and cognition. The interplay between exercise-induced physiological and psychological changes continues to incite interesting research and debate (McMorris, Tomporowski, & Audiffren, 2009).

It is believed that during acute bouts of exercise, command signals from the hypothalamus instigate changes in respiration and circulation and that a central command function of the brain activates transient autonomic nervous system modifications that in turn determine the cardiovascular responses to exercise (McMorris, Tomporowski, & Audiffren, 2009). These neural mechanisms both modulate and are themselves modulated based on particulars of the activity and the corresponding physiological responses and demands. The central nervous system collates input from the involved systems and regulates accordingly (Kashihara, Maruyama, Murota, & Nakahara, 2009). The brain initiates the decision or instinct to act then moderates the physiological variables involved in that action in a top-down regulatory process.

Even though the onset of fatigue from maximal physical exertion is accompanied by reduced blood flow and oxygen delivery, both system-wide and in the skeletal muscles, during maximal exercise in healthy humans, brain uptake of oxygen and lactate is enhanced (González-Alonso, Dalsgaard, Osada, Volianitis, Dawson, Yoshiga, & Secher, 2004) and remains elevated during the initial recovery phase after cessation of the activity (Ide & Secher, 2000). Cerebral blood flow actually increases during exercise despite the increased demands of the exercising muscles. Activation of the command functions of the brain associated with physical activity increases brain metabolism in the affected brain structures. However, Kayser (2003) suggests that high exercise intensities increase neuronal activity and that during exhaustive physical activity brain energy demand may exceed supply, resulting in malfunction.

Where does cognition fit into the complexity of brain function during exercise? Assessment of the acute psychological effects of exercise entails a variety of sensorimotor and cognitive processes that differ with reference to whether the exercise is aerobic or anaerobic, localized or systemic, of constant or incremental intensity, and brief or prolonged (McMorris, Tomporowski, & Audiffren, 2009). Sensorimotor processes are a primarily reactive interface between the brain and its environment, while cognitive processes are anticipatory and predictive. These two broad categories can each be further dissected into aspects distinct in both response and assessment (McMorris, Tomporowski, & Audiffren, 2009).

With reference to acute bouts of submaximal steady-state aerobic exercise, McMorris, Tomporowski, and Audiffren (2009) discuss a hypothetical bidirectional neurological effect. In general, performance of a cognitive task either improves or is impaired depending in part on whether it is an automatic, unconscious response to a stimulus or an effortful, conscious task. Assessment and interpretation of cognitive effects are complex and vary depending not only upon the task but also on the location along the continuum between extremes such as consciousness level, degree of effort, and other. Both positive and negative effects may occur simultaneously, as in a study that concluded that moderate aerobic exercise shortens visual and auditory reaction times but diminishes attention and increases error rates (Yagi, Coburn, Estes, & Arruda, 1999). Kashihara et al. (2009) discuss the possibility of an optimal juxtaposition between exercise and cognitive function—an activity level at which the select cognitive ability is best performed and above and below which performance is diminished, in an inverted U relationship, similar to the Optimal Performance Zone discussed by Palmer (2007). One research example is the finding that choice reaction time was optimal at a heart rate of

115 beats per minute (Levitt & Gutin, 1971) but was diminished at both lower and higher heart rates.

Cognition and Exercise

The diverse and creative research designs and the assorted outcomes of investigations of the effects of exercise on cognition do not afford decisive conclusions. Research on acute exercise and cognition has yielded mixed results. Studies attempting to define a dose-response relationship between cognitive performance and exercise intensity have suggested an inverted-U relationship (Arent & Landers, 2003), a linear relationship (Davranche & Audiffren, 2004; McMorris & Graydon, 2000), and no dose-response relationship (Cote, Salmela, & Papanthasopoulu, 1992). These differences are not discrepancies but are related to the different research designs and to variations in the demands of the cognitive task.

Though Davranche and McMorris (2009) found that response inhibition (congruency) deteriorated during acute moderate exercise, it is generally accepted that both acute bouts of moderate exercise (Davranche & Audiffren, 2004) and an ongoing regimen of regular physical activity over time (Colcombe & Kramer, 2003) improve cognitive function. Endurance athletes showed improvement in both simple and choice reaction time from baseline immediately after cycling exercise at 75% of maximal work capacity (Hogervorst, Reidel, Jeukendrup, & Jolles, 1996). With regard to acute bouts of intense physical activity, however, the contradictory findings and selective effects that vary with the psychological task and the exercise intensity and duration indicate the need for further studies (Brisswalter, Collardeau, & Rene, 2002).

From their meta-analysis of the effects of long-term fitness training on cognition, Colcombe and Kramer (2003) revealed significantly improved cognition, especially for executive control processes. Tomporowski (2003) reviewed studies on the effects of acute bouts of physical activity on adults' information-processing abilities and categorized these studies into the following three groups: brief maximal exercise protocols, arousal in short duration maximal and submaximal protocols, and submaximal exercise of longer duration. The author concluded that some aspects of information processing were improved in submaximal aerobic exercise performed up to 60 minutes but that information processing and memory were impeded during extended exercise, possibly from dehydration The relationship between exhaustive exercise and perception, sensory integration, or discrimination remains unclear, but response preparation processes such as coincidence-anticipation-timing (Isaacs & Pohlman, 1991) deteriorate with exhaustive exercise. Overall, though, only small transitory decreases in cognition have been found from intense anaerobic exercise (Tomporowski, 2003).

During progressively more intense submaximal treadmill walking, physical exertion facilitated performance on reaction time and decision-making tasks but degraded performance of an arithmetic task (Krausman, Crowell, & Wilson, 2002). Covassin, Weiss, Powell, and Womack (2007) saw a decrease in both immediate and delayed recall memory scores and no significant differences for visual memory, motor processing speed, and reaction time after a maximal exercise test, yet others observed a decline in the performance of both a submaximal muscle contraction and choice reaction time when simultaneously performed (Lorist, Kernell, Meijman, & Zijdewind, 2002). Chang and Etnier (2009) contend that the cognitive effects of resistance exercise have heretofore been ignored and concluded that high intensity resistance exercise benefits processing speed and moderate intensity resistance exercise benefits executive function. They predict new research directions and new variables in the cognition-exercise mix with resistance exercise and executive function.

The connection between exercise, physiological parameters, gender, and cognitive reactions has yet to be clearly defined or completely understood. Complete understanding may not be possible. Some cognitive functions are degraded by exercise and others are not—cognitive processes respond differently to exercise (Davranche & McMorris, 2009). A summary of studies on the acute cognitive effects of exercise collates a diverse array of variables and results interesting in breadth but difficult to coalesce into firm conclusions (Tomporowski, 2003). The brain initiates voluntary exercise which in turn facilitates cerebral and neurological reactions that cascade into other effects that may or may not facilitate or impede a particular aspect of cognitive function. Mental fatigue can alter perceived exertion and ability or willingness to continue a given activity. Practically speaking, either situation might cause a critical error in work situations **(**Marcora, Staiano, & Manning, 2009).

Physiological Effects of Respirator Wear

The prevalence of occupational respirator use necessitates accurate assessment of both the protection and limitations of the given respirator and the effects of the respirator on the wearer. When donning a respirator, the wearer necessarily accepts its discomforts and side effects in exchange for protection from a hazardous atmosphere. This necessary tradeoff is acceptable when the discomforts are reasonable and do not themselves cause potentially harmful physiological or psychological alterations. The environmental, physiological, and psychological factors related to respirator wear form a dynamic set of variables whose interactions cannot be predicted but must be anticipated. In a survey of respirator wearers, the most negative influences identified were communication, personal comfort, effect on vision, structural environment, and fatigue (Salazar, Connon, Takaro, Beaudet, & Barnhart, 2001). Fear and anxiety can impair cognitive and motor tasks (Eysenck, 1992) and generate physiological reactions such as increased heart rate, blood pressure, and respiration rate that are unrelated to work intensity. Add to these factors the increased energy demands of the body from the exercising muscles, brain processes, and the work of breathing (WOB) in a respirator. The potential additive stress is apparent though not entirely measurable.

The WOB refers to the effort required to inhale and exhale and considers the work of the muscles involved in breathing. It increases with activity, anxiety, disease or when breathing through mechanical respiratory devices (Zechman,, Hall, & Hull, 1957), and increased breathing resistances decrease performance (Caretti, Coyne, Johnson, Scott, & Koh, 2001) and increase oxygen consumption (Johnson, Dooly, & Dotson, 1995). In addition to respirator wear, the increased energy demand is due in part to the increased activity of the intercostals, diaphragm, abdominals, and other breathing muscles during respiration (Agostoni, Citterio, & D'Angelo, 1979). Raven, Dodson, and Davis (1979) suggested that such increased resistance on inspiration increases cardiac work due to an increase in the demands of the heart muscle itself in addition to the increased cardiac work due to increased demands of the breathing muscles. However, although elevation in heart rate is a usual response to increased energy demands, studies of heart rate response to respirator use have seen mixed results.

The combination of respirator wear, work, and thermal stress increases heart rate and respiration in an attempt to dissipate heat, and further increases the work of breathing, as shown in a study of the cardiopulmonary and thermal effects of respirators during work (Jones, 1991). Aside from a respirator-induced increase in breathing rate, heart rate during heavy work, systolic blood pressure during heavy work, diastolic blood pressure, and heat stress, there were clinically significant blood pressure changes during exercise in two subjects. Louhevaara, Tuomi, Korhonen, and Jaakkola (1984) saw respirator-induced increases in ventilation, heart rate, and oxygen, during both submaximal activity and the recovery there from with three types of respirators. As a result, they recommended that respirator wear warrants careful consideration of the need for rest periods and knowledge of the individual's work capacity.

Deno, Scott, and Kiser (1981) found that maximum exercise intensity and duration were significantly reduced due to resistance breathing. Others found a reduction of time to reach maximum exertion and an increase in oxygen consumption (Wilson, Raven, Morgan, Zinkgraf, Garmon, & Jackson, 1989). When heart rate, perceived exertion, and postural stability were measured with and without respirators, respirator wear produced higher perceived exertion ratings, a significantly higher heart rate, and decreased postural stability (Seliga, Bhattacharya, Succop, Wickstrom, Smith, & Willeke, 1991).

In a study of submaximal and maximal exertion with and without a respirator, while oxygen uptake was significantly greater and performance time to max decreased with the respirator, maximum heart rate and perceived exertion at maximal exertion were not significantly different (Wilson, Raven, Morgan, Zinkgraf, Garmon, & Jackson, 1989). A related study with subjects working at 70% of their predetermined maximum showed no significant difference in the average heart rates for respirator and non-respirator wear, although oxygen consumption increased and work performance to exhaustion time decreased with a respirator (Wilson & Raven, 1989). When Bardsley, Amtmann, and Spath (2005) assessed heart rate and blood pressure changes from wearing three types of respirator during submaximal cycle ergometry, they found no important treatment effects, though gender differences were statistically significant. In an unpublished aspect of the same study, heart rate and blood pressure were significantly lower in subjects with better cardiorespiratory fitness.

While some studies detail significant effects of respirator wear and exercise, others found no important differences in physiological parameters from these factors. Respirator resistance and dead space did not significantly affect exercising heart rate compared to no respirator wear (Harber, Tamimie, Bhattacharya, & Barber, 1982). This finding was supported in a later study in which heart rate and oxygen consumption were unaffected by respirator wear at rest and at low, moderate and maximal work loads (Harber, Tamimie, Emory, Bhattacharya, & Barber, 1984). The researchers contended that because heart rate changes from increased breathing resistance and dead space are small or nonexistent, a significant increase in heart rate occurring from respirator wear is an abnormal reaction. Verstappen, Bloemen, Van Putten, and Reuvers (1986) saw no important differences in heart rate or maximum work load with or without a respirator and concluded no significant effect on aerobic exercise with industrial respirators.

The physiological changes due to activity and/or respirator wear may pose a safety or health risk in many work situations. Consider, too, that in addition to the worker that is personally affected, the risk may extend to other workers and to the work environment. Performance standards for those required to wear respirators are rare, but the American Industrial Hygiene Association (AIHA) recommends that respirator wearers wear the respirator for 30 minutes, during which the individual should perform at a work intensity equivalent to the job task (Sharkey & Davis, 2008). Such a screening could help determine respirator anxiety and the magnitude of physiological and psychological respirator effect during work.

Respirator Wear, Cognition, and Exercise

Wearing a respirator is subjectively unpleasant due to both physiological and psychological factors such as discomfort, increased breathing effort (Jones, 1991), communication difficulty (Johnson, Scott, & Caretti, 2000), and anxiety (Johnson, Dooly, Blanchard, & Brown, 1995). Quantitatively, though, studies of cognitive responses during respirator wear have yielded results that vary both in magnitude and direction.

A study of the effects of respirator wear on cognitive performance of at-rest computer-controlled tasks showed no important differences in reaction time and response accuracy related to respirator wear. Mean decision-making times were significantly faster during respirator wear for select tasks, and female reaction times were faster than male. The researchers concluded that cognitive ability is not adversely affected by respirator wear in non-exercise conditions for durations up to 3-4 hours (Caretti, Bay-Hansen, & Kuhlmann, 1995).

Caretti (1997) subsequently studied non-exercising cognitive performance during two 10-hour trials, one with and one without a respirator, and found no important differences in reaction time, visual tracking ability, and decision-making speed, though female reaction time and decision-making speeds were faster than male. Even though the findings suggest that respirator wear over a normal work shift under non-exercise conditions does not adversely affect cognitive ability, subject anxiety increased significantly after 8 hours of testing in both trials. Anxiety triggers behavioral, physiological, and cognitive response systems that are not altogether controllable by the individual and degrades both cognitive and psychomotor performance, particularly for difficult or complex tasks or under stressful conditions (Eysenck, 1992).

Respirator anxiety can increase discomfort and decrease performance in anxious subjects (Johnson, Dooly, Blanchard, & Brown, 1995). Wilson, Raven, Morgan, Zinkgraf, & Jackson (1989) found that 89.5 percent of subjects with elevated trait anxiety scores experienced respiratory distress during a maximal exercise test while wearing a full-face piece, air-line pressure-demand respirator. In another study, however, decision-making and mood during respirator wear showed no important cognitive or mood-related effects from respirator wear during one hour of low-intensity exercise (Caretti, 1999).

Respirator wear did not significantly affect cognitive task performance in a study of the effects of three types of respirators on performance of physical, psychomotor, and cognitive tasks during cycle ergometry. Respirator effects were, however, seen in performance of psychomotor tasks such as steadiness and movements requiring accurate control. A 10 percent increase in oxygen consumption for the half and full-face mask trials was also noted, indicating an increase in physiological work due to wear of tight-fitting respirators (Zimmerman et al., 1991).

Gender Differences, Cognition, and Exercise

In general, females are underrepresented in physiological research, with cognition research being no exception. Studies including both genders often yield gender-specific results. However, the premise that males and females differ significantly regarding cognitive abilities was refuted in Hyde’s (1981) meta-analysis of the extent of gender differences in which she found that that gender differences in verbal ability, quantitative ability, visual–spatial ability, and for field articulation, were not significant. When Jensen (1998) reviewed intelligence tests, he concluded no overall gender differences, though individual tests yielded differences, with the size and direction depending on what and how it is measured. Overall, there is no gender difference in intelligence, but differences in response to individual assessments, as shown in a study of gender and health variables on cognitive abilities (Jorm, Anstey, Christensen, & Rodgers, 2004).

The structural and hormonal differences between males and females influence their cardiorespiratory differences. In general, females have lower lung function, muscular strength, and functional capacity—all factors in work performance and respirator wear (Harms, 2006; Sharkey & Davis, 2008). This, in turn, affects their breathing rates and gas exchange during exercise. These factors, along with structural differences such as smaller airway diameter, increase the work of breathing. Overall, for women, pulmonary effects in turn may limit their functional capacity as compared to men. Thus, to accomplish a given workload, women must work harder. However, the significant differences in physical characteristics between genders do not translate to differences in oxidative stress (Pepe, Balci, Revan, Akalin, & Kurtoglu, 2009).

In a comparison of physiological gender differences in a cohort of similarly active males (n=10) and females (n=10) doing submaximal cycle ergometry, there was no significant difference between genders in heart rate, temperature, relative oxygen uptake, or diastolic blood pressure to exercise of the same relative intensity. Post-exercise recovery rates did not differ, though males had significantly higher systolic blood pressure and respiratory exchange ratio (Abraham, Wilson, Deschenes, 2005).

In a study of the effects of acute maximal exercise on cognitive function in young women, fit women had faster simple reaction time than sedentary, but there was no effect on simple reaction time due to exercise intensity. A decline in visual spatial memory and working memory during and immediately after acute maximal exertion improved after recovery from the exercise (Bue-Estes, Willer, Burton, Leddy, Wilding, & Horvath, 2008). In a related study of female subjects, although no effect for time or cognitive function was seen following short-term maximal exercise, fit subjects performed better than sedentary (Bue-Estes, Horvath, Burton, Leddy, & Willer, 2005).

It is naïve to think that gender differences do not or should not exist or that their direction somehow infers superiority. Identifying such differences is important, not in the battle of the sexes, but in understanding the characteristics of each gender so that the uniqueness is not only identified (and hopefully appreciated) but also accounted for if needed. In this study, and practically speaking, gender differences and limitations may be important in workload and respirator type determination.

Summary of Chapter Two

Although the effects of physical activity on cognitive abilities have been diversely investigated, contradictory findings and selective effects that vary with the psychological task and the exercise parameters warrant further studies to refine and broaden current knowledge. Similarly, studies of respirator effect on cognitive abilities have yielded varied and sometimes incongruent results that are disparate due to design factors such as differences in activity modes, intensities and duration, respirator types, and cognitive tasks. The absence of studies on the cognitive effects from performing short-term, maximal exertion while wearing a respirator affirms the importance of this research.

In Chapter three, Methodology, the research design, equipment, and protocols used in conjunction with the cognitive data collection are explained. The research design and collection of the archival data for this project is described. The statistical analysis method and level of significance are described, and the study limitations are discussed.

CHAPTER THREE

METHODOLOGY

Introduction

Not only has this study addressed gaps in the existing research regarding overall and gender-specific cognitive changes from maximal exertion with or without respirator wear, but it may also initiate scrutiny of and change in respirator screening requirements. Important detrimental changes as indicated by lower scores and increased times on the Mini Mental State Examination (MMSE) cognitive assessment (Folstein, Folstein & McHugh, 1975) would suggest the need to strengthen federal regulation of respirator wear with regard to worker health and fitness, work intensity, and respirator wear and selection. Unimportant differences contribute to the body of respirator research and activity and suggest directions for future research.

In order to assess transient cognitive impairment due to differences in activity level, respirator wear, and gender, archival data were tested for statistically reliable differences in both total and sectional MMSE scores and times. In addition, differences in the magnitude of individual subject changes were evaluated. Cognitive impairment was assumed with a statistically reliable decrease in MMSE scores and increase in MMSE times. Cognitive improvement was assumed with a statistically reliable increase in MMSE scores and decrease in MMSE times. The research questions are now summarized before detailing the methodology.

Research Questions

The research questions posit whether significant differences exist in the response variables with regard to treatment, gender, and individual subject response. Each of the four treatments includes components of activity level and respirator wear. Research questions 1 and 2 ask whether cognitive function will vary significantly due to activity level or respirator usage differences. Research question 3 asks whether there are significant differences in cognitive function response between males and females. Research question 4 asks whether the main effects of treatment and gender together have an interactive effect on cognitive function. Research question 5 asks whether there will be significant variance in cognitive function measurements due to individual subject response differences. These questions were answered through statistical testing of 10 hypotheses, the results of which are detailed in Chapter Four.

Population and Sample

The sample consisted of 18 subjects from the population of healthy active college students. There were 9 of each gender, all 18-25 years of age (mean 21.2 ± 1.8 years). They were volunteers pre-screened regarding physical activity profile, health, and for ability to wear a respirator. An equal representation of males and females was sought to allow gender comparisons. This purposeful, homogeneous sample was solicited to reduce risk and discomfort from the maximal physical exertion required for this study.

Research Design

This research is an ex post facto causal comparative study that examined whether there are transient changes in cognitive function from maximal exertion and respirator wear as indicated by differing scores and times from the MMSE, a brief assessment of cognitive ability. The data were collected during two repeated measures studies directed by this researcher that explored the physiological effects of maximal activity and respirator wear (Anderson, Sullivan, Bardsley, & Jensen, 2010). Subjects performed the Wingate Anaerobic Test (WAnT), a well-known anaerobic cycle ergometry protocol requiring subjects to pedal as fast as possible for 30 seconds at a prescribed resistance. The MMSE was administered immediately upon cessation of the WAnT.

Data Collection

For this research, the term ‘treatment’ denotes both activity level, whether resting or post-WAnT, and respirator usage, whether wearing or not wearing a respirator. The four treatments each incorporate both an activity intensity component and a respirator usage component and include a resting no-respirator trial and three post-WAnT trials with or without respirator wear. The conditions under which data were collected were the following:

1. At rest wearing no respirator (R);
2. Immediately after performance of the WAnT wearing no respirator (N);
3. Immediately after performance of the WAnT wearing a half face air-purifying respirator (P); and
4. Immediately after performance of the WAnT wearing a half face air-supplying respirator (S).

The MMSE, a brief assessment of cognitive ability, was administered for each research condition. The MMSE data recorded and archived for future consideration were the data analyzed for this research. Please see Appendix C, Table C, Summary of Trial Periods, Durations, Activities & Measurements, for a description of each trial from start to finish.

Institutional Review Board Approval. This project and those from which the data were archived were each approved by the University of Montana Institutional Review Board (IRB).

Equipment and Protocols

An array of instruments and supplies was used for both physiological and cognitive data generation and collection. In addition, a cycle ergometer protocol and a psychological assessment instrument were used to standardize activity and response variables. The equipment and protocols relevant to this study are described below.

Equipment

The WAnT requires calculation of a specific workload based upon the subject's weight and fitness. A Monark cycle ergometer provided the measurable workload for the WAnT. Respirator effect and the comparison of two different respirators were key to this research. Half face 3M respirators were used for both respirator treatments.

Monark cycle ergometer. Cycle ergometers allow quantitative measurement of physiological workload or resistance during cycling. The ergometer resistance for the warm-up, sprints, and WAnT was manually adjusted on a calibrated Monark cycle ergometer. Workload in newtons for each subject was calculated based on subject gender, body weight, and fitness level. Figure 1 shows a Monark cycle ergometer.

Figure 1

Monark Cycle Ergometer

Respirators. Tight-fitting half face 3M respirators were worn for all respirator treatments. For the air-purifying respirator (P) treatment, N-95 particulate filters were attached to the inhalation ports. For the air-supplying respirator (S) treatment an adapter provided by 3M was connected to the respirator and to an airline connected to a Gast continuous low-flow pump that supplied air into the mask at a constant rate of 150 liters per minute.

Protocols

Two well-known protocols were used to standardize the activity and cognitive assessment. The WAnT provided the anaerobic activity for the respirator and non-respirator usage. The MMSE was administered immediately after cessation of the WAnT and at a separate session. Scores and completion times were recorded to measure possible cognitive changes. A description and discussion of each protocol follows.

Wingate Anaerobic Test (WAnT). Anaerobic performance tests are high-intensity maximal effort exertions that can last from seconds to several minutes. The WAnT has become the most widely used laboratory test of anaerobic muscle power, muscle endurance, and fatigue since its development in Israel in the 1970s. The WAnT is a 30-second all-out sprint on a cycle ergometer. After several minutes of submaximal warming up, the subject pedals as hard and fast as possible for a full 30 seconds against a prescribed ergometer resistance that is calculated as a fraction of body weight in newtons (Inbar et al., 1996). From the WAnT it is possible to assess mean, peak, and relative anaerobic power and work, as well as percent fatigue from highest to lowest effort. WAnT correlation coefficients as high as 0.89 to 0.99 have occurred, but vary depending on the focus of the analysis (Barfield, Sells, Rowe, & Downs, 2002).

Figure 2

Subject Performing WAnT Wearing a Half-face Air-purifying Respirator

Mini Mental State Examination (MMSE). The cognitive data for this study is MMSE scores and times that were collected immediately after cessation of the WAnT for three treatments and resting wearing no-respirator for the fourth treatment. The MMSE consists of a selection of questions and tasks designed to assess cognitive function in adults. It was chosen for this research because it assesses a range of cognitive skills and was easily adaptable for rapid timed oral administration.

The MMSE was developed by Folstein, Folstein and McHugh (1975) to standardize and quantify mental status and the cognitive state. It is used to screen for cognitive impairment such as dementia and Alzheimer's disease and as an outcome measure to show cognitive change but is not for diagnosis of cognitive deficiency. Studies have shown that for both normal and cognitively impaired persons, MMSE test-retest reliability ranges from approximately 0.79 to 0.87 (Folstein, Folstein, & Fanjiang, 2001).

The MMSE assesses general cognitive function at a given point in time (Folstein, Folstein & McHugh, 1975). The total score is the sum of 11 sectional scores for the MMSE sections and aspects of cognition described below. The scores (S0-S11) were based on subject answers and performance of required tasks, during which the response time (T0-T11) for each section was recorded. The score and time codes and point value of each is indicated.

1. *Orientation to time* (S1, T1) required saying the day, date, and season to assess awareness of one's temporal point of reference. (5 points)
2. *Orientation to place* (S2, T2) required saying the specific location, city, and state to assess awareness of one's physical point of reference. (5 points)
3. *Registration* (S3, T3) required repetition of three unrelated words verbalized by the tester to assess immediate recall. For this study, these words were changed for each treatment. (3 points)
4. *Attention and calculation* (S4, T4) required verbalizing the answers of mental serial subtraction of 7 from the starting number to assess calculation ability. For this study, the numeric starting point was changed for each treatment. (5 points)
5. *Recall* (S5, T5) required recollection of previously repeated words (from #3) to assess short term memory. (3 points)
6. *Naming* (S6, T6) required recognition of and naming common objects held up by tester. For this study, different random objects such as a pen or a watch were used for each treatment. (2 points)
7. *Repetition* (S7, T7) required repeating the phrase "no ifs, ands, or buts" after verbalized by tester. (1 points)

8. *Comprehension* (S8, T8) required performing the three-stage command “Pick up this paper in your left (or right) hand, fold it in half, and set it on the table” after verbalized by tester to assess understanding and sequential task performance. (3 points)
9. *Reading* (S9, T9) required silently reading “Close your eyes” on a piece of paper and doing so to assess understanding. (1 points)
10. *Writing* (S10, T10) required writing a sentence on paper. (1 points)
11. *Drawing* (S11, T11) required being given a paper depicting two intersecting pentagons and correctly reproducing the design on paper. (1 points)

The maximum possible total MMSE score is 30 points. Each of the 11 individual sections is of variable worth (Folstein et al., 2001). See Appendix D, Figure D1 for the adapted MMSE form and questions used for this project.

The MMSE was not designed as a timed test. For this research, oral administration and scoring of the MMSE was accomplished by the same researcher for all treatments. Timing was performed by three different researchers. Each of the 11 individual sections and the total test were timed to the nearest second to evaluate whether activity and respirator wear affected test duration. To eliminate the need for the test administrator to take time to record answers, the MMSE answer form was adapted so that correct answers to items 1-7 were quickly indicated by the researcher with a dash if correct. No dash indicated error. Items 8-11 were tasks that required subject action, with the duration of each timed. Total and sectional MMSE scores and times were recorded and collated. The scores were in points, with 30 points being the maximum total score and the individual section scores ranging from one to five points.

The expanded use of the MMSE from a tool for clinical assessment of cognitive impairment to that of an instrument for assessing transient cognitive changes in healthy adults broadens its scope and application. It was chosen after conferring with a psychologist that advised looking for an appropriate instrument in The Fifteenth Mental Measurements Yearbook (Plake, Impara, & Spies, 2003), a compilation of evaluations of standardized tests in a variety of categories. The goal was to find a tool that evaluated a spectrum of cognitive areas, was short and easily administered, and that produced quantitative data to enable analysis and comparison of different treatments. The MMSE met these goals.

The streamlined standardized administration used in this study allowed for rapid timed response measurement over a range of cognitive areas, enabling assessment of both scores and response time. Researchers agree that a standardized cognitive assessment battery would allow for comparisons of studies on cognition (Etnier et al., 2006). Adaptation of the MMSE as such an assessment would be a good start.

Archival Data Collection Procedures

At each trial, the MMSE was orally administered and the answers recorded by this researcher immediately after cessation of the WAnT, while the subject was slowly pedaling the ergometer to cool down. The MMSE question form shown in Appendix D, Figure D1 was adapted so that answers could be indicated by a dash. The tasks required of the subject were performed on a tray secured on the ergometer handlebars by a member of the research team. The corresponding times for each answer and task were recorded on a duplicate form by a research assistant. Answers and times were collated on the original score sheet after administration and interpreted by this researcher.

Variables and Level of Data

The independent or predictor variables are the treatments—the resting and activity-related comparisons combined with the respirator wear comparisons—and gender, with subject as a random variable. The resting no-respirator condition (R) data were compared to the exercising values for no respirator (N), air-purifying respirator (P), and air-supplying respirator (S) treatments to assess differences due to maximum exertion. The N, P, and S data were compared for differences due to respirator usage. Gender comparisons were made with regard to activity and respirator usage.

The dependent or response variables for this study are the total and sectional MMSE test scores and times. Each response variable is designated by a letter-number combination. Scores are S0-S11 and times are T0-T11, with S0 and T0 being total scores and times and S1-11 and T1-11 being the sectional scores and times. The numbers correspond to the section numbers on the MMSE score form. For both the MMSE scores and times the level of data is ratio. The total possible score is 30. The possible scores for the individual MMSE sections vary and range from one to five points. The times are in seconds, with zero minimum and no maximum time limit.

Data Analysis

For purposes of statistical analysis, it was assumed that the study subjects were a representative sample of the population of active, healthy young college students. The statistical software package Minitab was used to carry out the analyses with regard to two main factors—treatment and gender—and 24 response variables—12 MMSE scores and 12 times (one total and 11 sectional in each category). The interaction between treatment and gender was also considered, as was the effect of individual subject response, with subject as a random factor. The four treatments are one resting with no-respirator (R);

and three post-WAnT treatments with no respirator (N), an air-purifying respirator (P), or an air-supplying respirator (S), respectively. Statistical importance is set below an alpha level of .05 ($p < .05$).

The null hypotheses were tested using the Minitab ANOVA general linear model (GLM) to perform multivariate analysis of means with gender and treatment as fixed factors to assess the significance of the main effect for each factor and the interaction between them. Subject was also included in the model as a random factor to investigate variations in individual subject response. Where treatment proved significant, Bonferroni 95% Confidence Intervals were calculated to determine the treatment pairs that were important.

Limitations and Assumptions

The several limitations and assumptions related to this research may affect both the validity and reliability of the results. The major threats to validity in this study include small sample size, non-random treatment order, generalization of results, instrument validity, carryover effect, and rater differences. In addition, several subject-related assumptions must be considered as possible sources of error.

Limitations

Small samples size is a limitation to the generalization of this study. While the sample was always intended to be purposeful and non-random, the initial goal to recruit at least 30 subjects to lend statistical credibility to the results was initially met. However, attrition decreased the total in all phases of the research to 18 subjects. Budgetary constraints also limited subject numbers in the subsequent study, as subjects were paid an honorarium.

The treatment order for this research was not random. The archival data for this study were collected in increments, so random ordering of the treatments was not possible. The broad scope of this research was not initially defined—one study led to the other, all with the same subjects. The N and P treatments were randomly administered in the initial study, after which the scope of the study broadened to include a resting no-respirator component and the post-WAnT air-supplying respirator component. The resting non-treatment (R) data were collected one month after N and P. Three months after the initial study, the air-supplying treatment (S) was conducted. Because the treatments were not randomly ordered, this constitutes a threat to internal validity because of possible carryover effects. Repeated performance of both the WAnT and the MMSE in the trials could have contributed to improved performance due to increased familiarity with the protocols and possible improvement or alteration in both physical and cognitive performance in subsequent trials.

The results of this study cannot be generalized to any broader population beyond that of active, healthy young college students due to purposeful selection of study subjects. The sample was intentionally purposeful and homogeneous regarding age, health, and activity. The subjects were not randomly chosen from any population but were volunteers whose selection was based on uniform characteristics for the following reasons:

1. It was assumed that young, healthy, fit individuals would be able to complete the rigorous WAnT protocol successfully and safely.
2. Due to the sample’s similar characteristics regarding education level, health, age, and gender representation, more uniform effects not readily apparent in a small random sample may be seen. While the results of this research cannot

be generalized beyond the population of young, active, healthy college students, it is possible that effects seen in this sample may be more profound or have critical implications with regard to older and/or less healthy individuals working in a challenging environment.

The ecological validity of this study is threatened because these data were collected in a controlled, comfortable environment that was safe, private, quiet, well illuminated, and of a constant, moderate temperature of 70 degrees Fahrenheit. In addition, the subjects wore light, comfortable clothing—t-shirts, shorts, and athletic shoes—and performed cycle ergometry, a controlled task that does not represent any normal work activity. The environmental conditions, the subject attire, and the activity mode were not akin to those of most real-world working conditions, which may vary significantly and critically with regard to hazard potential, task rigor, temperature, noise, lighting, required clothing, and other factors. Such factors may cause considerably greater worker stress in actual working conditions. Thus, the results of this research cannot be accurately extrapolated to actual working conditions or to actual workers. It can be theorized, however, that similar research in real-world conditions may have more robust and profound results.

The use of the MMSE to identify transient cognitive changes in normal, healthy young adults has not been previously conducted. It is most commonly used in a clinical setting to determine the cognitive status of a patient. It is assumed that the questions and tasks on the MMSE evaluate cognitive ability in general, regardless of innate cognitive status, and that their sensitivity is sufficient to detect transient cognitive changes in one individual. Timing of MMSE responses adds a new dimension to administration of this assessment. Nor has administration of the MMSE as a timed test been previously conducted. Intra-rater verbal administration and inter-rater timing reliability are assumed such that differences in MMSE response times are due to activity and respirator usage effect and not to testing effect or researcher bias.

Assumptions

The following assumptions were made regarding subject condition and compliance.

1. Subject motivation, fitness level, and degree of effort were the same for each condition.
2. Subjects complied with instructions regarding pre-trial exercise and substance intake restrictions that could have affected both physiological and cognitive responses. Compliance was not specifically verified at each trial.

Summary of Chapter Three

The sample from which the archival data were collected was a purposeful, selection from the population of healthy, active college students. The subjects were 18 healthy active college students that completed two studies regarding the cognitive and physiological effects of maximal exertion and respirator wear. The treatments occurred at separate trials and were comprised of an activity component and a respirator usage component. The R resting no-respirator treatment was compared to the post-WAnT treatments N (no respirator), P (air purifying respirator) and S (air-supplying respirator) to assess cognitive differences from activity level differences. The N, P, and S treatments were compared to assess cognitive changes due to respirator usage differences. Differences between genders were analyzed. At each exercising trial, the MMSE was orally administered and the answers and times were recorded immediately after cessation of the WAnT. The sundry limitations and assumptions of this research suggest prudent application of the results to a finite population but with careful consideration of the possible implications for other populations.

The Minitab General Linear Model two-way ANOVA with interaction was used to analyze total and sectional MMSE scores and times with respect to gender and N, P, R, and S treatments. Statistical significance was set below an alpha level of .05 ($p < .05$). The statistical and descriptive results are reported in Chapter Four.

CHAPTER FOUR

RESULTS

Introduction

The results of this evaluation of transient cognitive changes from maximal exertion and respirator wear expand the knowledge about overall and gender-related differences in cognitive function due to respirator wear and/or short term maximal exertion. In this research, adverse changes in cognitive function indicated by lower scores and increased response times on the MMSE would suggest the need to strengthen federal regulation of respirator wear with regard to worker health and fitness, work intensity, and respirator wear and selection.

The components of the MMSE reflect a comprehensive view of cognition. There are 11 sections of the MMSE, each focusing on a particular facet of cognitive and/or psychomotor function. Each is scored separately and all are combined into a summary score meant to be an index of cognitive status at the time of the assessment (Folstein, Folstein, & McHugh, 1975). The total and 11 sectional MMSE scores and times were analyzed for statistically reliable difference or change ($p < .05$) with regard to treatment, gender, and individual subject variability. For this research, the term ‘treatment’ denotes one of two activity conditions in tandem with one of three respirator usage conditions. The activity conditions were either seated at rest or immediately after performance of the Wingate Anaerobic Test (WAnT), a 30-second all-out maximal exertion at a prescribed resistance performed on a cycle ergometer. The respirator usage conditions were no respirator, wearing an air-purifying respirator, or wearing an air-supplying respirator.

The following four treatments were compared: at rest wearing no respirator (R); immediately following performance of the WAnT wearing no respirator (N); immediately following performance of the WAnT wearing an air-purifying respirator (P); and immediately following performance of the WAnT wearing an air-supplying respirator (S). Between and among treatments, genders and subjects, impaired or inferior cognitive function is assumed with decreased or lower MMSE scores and increased or greater MMSE times. Conversely, improved or superior cognitive function is assumed with increased or higher MMSE scores and decreased or shorter MMSE times between and among treatments, genders and subjects.

Population and Sample

From the population of healthy active college students, the sample for this research consisted of 18 subjects 18-25 years old (mean 21.2 ± 1.8 years). There were 9 of each gender, and all were volunteers pre-screened regarding physical activity profile, health, and for ability to wear a respirator. An equal representation of males and females was solicited to allow gender comparisons. The purposeful, homogeneous sample was solicited to reduce risk and discomfort from performance of the WAnT. The subject characteristics are summarized in Table 1.

Table 1

Subject Characteristics Means (M) and Standard Deviations (SD)

Category	**Age** years	**Height** centimeters	**Weight** kilograms
Overall *M* (N =18)	21.2	177.4	78.7
SD	1.8	8.7	14.6
Female *M* (n = 9)	20.2	172.7	70.4
SD	1.4	8.2	11.7
Male *M* (n = 9)	22.1	182.0	87.0
SD	1.8	6.4	12.4

Research Questions and Related Hypotheses

The overarching question of this study was whether cognitive function undergoes transient or short-term changes due to intense physical activity and respirator usage differences. This question is addressed by the five research questions and ten hypotheses developed for this study. Each tackles particular aspects of this collective theme to more concisely describe transient changes in cognitive function that occur with regard to several individual and interactive factors. To answer these questions, differences in both total and sectional MMSE scores and times were tested for statistical reliability ($p < .05$) with reference to activity level, respirator usage, gender, and individual subject response variance. The following research questions and associated null hypotheses (H_0) were considered.

Research Question 1 – Activity Effects

Will the cognitive function of healthy, active college students vary significantly due to activity level differences? This question will be answered by testing the following null hypotheses.

H_0 1 - Activity differences will not produce a statistically reliable effect on total or sectional MMSE scores.

H_0 2 - Activity differences will not produce a statistically reliable effect on total or sectional MMSE times.

Research Question 2 – Respirator Wear Effects

Will the cognitive function of healthy, active college students measured after maximal exertion vary significantly due to respirator usage differences? This question will be answered by testing the following null hypotheses.

H_0 3 - Respirator usage differences will not produce a statistically reliable effect on total or sectional MMSE scores.

H_0 4 - Respirator usage differences will not produce a statistically reliable effect on total or sectional MMSE times.

Research Question 3 – Gender Differences

Will the cognitive function of healthy, active college males and females differ significantly from one another due to activity level or respirator usage differences? This question will be answered by testing the following null hypotheses.

H_0 5 - Gender differences will not produce a statistically reliable effect on total or sectional MMSE scores.

H_0 6 - Gender differences will not produce a statistically reliable effect on total or sectional MMSE times.

Research Question 4 – Interactive Effects

Will the cognitive function of healthy, active college students vary significantly due to the interaction of treatment (activity intensity, respirator usage) and gender? This question will be answered by testing the following null hypotheses.

H_0 7 - Gender and treatment in interaction will not produce a statistically reliable effect on total or sectional MMSE scores.

H_0 8 - Gender and treatment in interaction will not produce a statistically reliable effect on total or sectional MMSE times.

Research Question 5 – Individual Subject Response Variance

Will there be significant variance in cognitive function measurements due to individual subject response differences? This question will be answered by testing the following null hypotheses.

H_0 9. Variance in individual subject response measurements will not produce a statistically reliable effect on total or sectional MMSE scores.

H_0 10. Variance in individual subject response measurements will not produce a statistically reliable effect on total or sectional MMSE times.

Data Analysis

Before statistical analysis, data were screened and values were rechecked to insure numeric and interpretive accuracy. Data were categorized according to predictor and response variables and means and standard deviations were calculated. Before formal analysis ensued, the data were scrutinized regarding the assumptions required for the analysis of variance (ANOVA), after which formal analysis was conducted. No analysis was performed on the 8 sectional score variables in which no differences occurred and therefore which showed no effect. Analysis for all other dependent variables was conducted with the progression of analysis indicated by the results of the initial ANOVA. These analyses are detailed in Appendix E, Tables E1-E17. In addition, effect size as indicated by omega squared (ω^2) was calculated for statistically reliable results. Effect size denotes the degree of cause-effect association between the independent and dependent variables of interest and is an index of the strength or importance of this relationship.

The overall and gender-specific means are presented for an initial assessment of the data, segregated according to scores and times. For this data set, means, mean differences, and standard deviations provide a preliminary look at response differences relative to the predictor variables and reveal trends not seen from inferential statistics. Inferential statistics can be usefully augmented by examination of other information and observations for a richer, deeper view and understanding of the data and nuances of effect that may have been missed by one approach alone. The following tables of overall and gender-specific means and overall standard deviations are followed by the results of a formal ANOVA. The results for each response variable are then presented, after which the answers to the research questions and the results of the null hypotheses testing are addressed.

The matrices in Appendix F integrate and summarize the descriptive and statistical findings of this study for all variables. Table F1 illustrates MMSE scores and Table F2 illustrates MMSE times. The statistical findings, a comparison of overall and gender-specific means, and direction of effect are shown. These tables assemble the various facets of this study into one representation that allows a view of the discrete parts, the whole, and the interrelationships and trends indicated by the data.

Means and Standard Deviations

The mean total and sectional scores in points for each treatment and the overall standard deviation are shown in Table 2. The means for each gender are also listed. The maximum point value for each score is parenthesized with the variable name. Table 2 is integrated into Table F1 in Appendix F, which combines statistical and descriptive results for all variables. The tables in Appendix F combine descriptive and statistical parameters, thus allowing an integrated view of the results.

Table 2

Overall, Female, and Male Mean Treatment Scores (points) and Standard Deviations (N=18)

SCORE Variables	**N** **Mean (SD)** **F M**	**P** **Mean (SD)** **F M**	**R** **Mean (SD)** **F M**	**S** **Mean (SD)** **F M**	**Overall** **Mean (SD)** **F M**
S0 Total (30)	28.3 (1.2) 28.0 28.6	28.6 (1.3) 28.4 28.7	29.4 (0.6) 29.6 29.2	28.7 (1.4) 28.6 28.9	28.9 (1.2) 28.8 28.9
S1 Orientation to time (5)	4.6 (0.5) 4.4 4.7	4.9 (0.3) 4.9 4.9	5.0 (0.0) 5.0 5.0	4.8 (0.6) 4.7 4.9	4.8 (0.4) 4.7 4.9
S2 Orientation to place (5)	5.0 (0.0) 5.0 5.0	5.0 (0.0) 5.0 5.0	5.0 (0.0) 5.0 5.0	5.0 (0.0) 5.0 5.0	5.0 (0.0) 5.0 5.0
S3 Registration (3)	3 .0 (0.0) 3.0 3.0	3 .0 (0.0) 3.0 3.0	3 .0 (0.0) 3.0 3.0	3 .0 (0.0) 3.0 3.0	3 .0 (0.0) 3.0 3.0
S4 Attention & calculation (5)	4.0 (0.8) 3.9 4.1	4.3 (0.9) 4.1 4.4	4.6 (0.3) 4.6 4.7	4.3 (1.0) 4.2 4.4	4.3 (0.8) 4.2 4.4
S5 Recall (3)	2.8 (0.4) 2.8 2.8	2.6 (0.9) 2.8 2.3	2.8 (0.4) 3.0 2.7	2.9 (0.3) 2.9 2.9	2.8 (0.3) 2.9 2.7
S6 Naming (2)	2 .0 (0.0) 2.0 2.0	2 .0 (0.0) 2.0 2.0	2 .0 (0.0) 2.0 2.0	2 .0 (0.0) 2.0 2.0	2 .0 (0.0) 2.0 2.0
S7 Repetition (1)	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0
S8 Comprehension (3)	3 .0 (0.0) 3.0 3.0	3 .0 (0.0) 3.0 3.0	3 .0 (0.0) 3.0 3.0	3 .0 (0.0) 3.0 3.0	3 .0 (0.0) 3.0 3.0
S9 Reading (1)	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0
S10 Writing (1)	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0
S11 Drawing (1)	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0

The summary of mean total and sectional MMSE times in seconds for each variable is shown in Table 3. Mean values for each treatment and overall, along with the overall standard deviation, are shown. The means for each gender are also listed. Table 3 is integrated into Table F2 in Appendix F, which combines statistical and descriptive results for all variables.

Table 3

Overall, Female and Male Mean Treatment Times (seconds) and Standard Deviations (N = 18)

TIME Variables	**N Mean (SD)**	**F**	**M**	**P Mean (SD)**	**F**	**M**	**R Mean (SD)**	**F**	**M**	**S Mean (SD)**	**F**	**M**	**Overall Mean (SD)**	**F**	**M**
T0 Total	127.8 (17.7)	139.3	116.3	121.6 (13.3)	130.0	113.2	109.8 (12.2)	116.6	103.1	104.6 (12.2)	109.0	100.2	116 (17.0)	123.7	108.2
T1 Orientation to time	14.1 (2.7)	14.0	14.1	13.0 (2.4)	14.0	12.0	12.9 (4.4)	12.9	12.9	12.2 (2.7)	13.2	11.2	13.0 (2.8)	13.3	12.6
T2 Orientation to place	12.2 (2.3)	12.4	11.9	11.6 (1.3)	12.6	10.7	10.3 (1.7)	10.8	10.2	9.8 (1.6)	9.9	9.8	11.0 (2.0)	11.4	10.6
T3 Registration	10.7 (3.6)	10.7	10.7	10.3 (2.3)	10.8	10.2	9.4 (1.8)	9.1	9.8	7.7 (1.2)	7.7	7.7	9.6 (3.6)	9.6	9.6
T4 Attention & calculation	27.9 (11.1)	33.0	20.8	26.1 (8.4)	30.8	21.4	24.6 (8.2)	29.9	19.3	24.2 (9.3)	29.2	19.2	23.7 (9.2)	31.2	20.2
T3 Recall	3.2 (2.0)	3.0	3.4	3.8 (2.2)	6.1	3.4	3.3 (1.2)	3.0	3.6	4.3 (1.2)	4.1	4.6	3.2 (1.8)	3.1	3.3
T6 Naming	3.3 (1.3)	3.9	4.8	3.7 (1.4)	3.4	3.9	3.0 (1.0)	4.9	3.0	3.2 (0.7)	3.0	3.4	3.3 (1.2)	3.3	3.3
T7 Repetition	7.2 (1.3)	7.3	7.0	6.6 (1.8)	7.0	6.1	6.6 (0.7)	6.6	6.6	3.9 (1.3)	3.7	6.1	6.3 (1.4)	6.6	6.4
T8 Comprehension	14.2 (7.1)	13.9	12.6	14.4 (2.6)	14.9	14.0	11.6 (1.6)	11.7	11.4	11.6 (2.3)	12.0	11.2	13.0 (4.2)	13.6	12.3
T9 Reading	3.0 (2.2)	3.3	4.7	4.3 (2.3)	4.0	4.7	3.7 (1.0)	3.8	3.7	4.0 (3.0)	2.8	3.2	4.3 (2.3)	4.0	4.6
T10 Writing	10.8 (3.7)	12.2	9.3	10.3 (2.6)	10.6	10.4	9.3 (1.3)	9.7	8.9	9.9 (2.3)	9.2	10.6	10.1 (2.7)	10.4	9.8
T11 Drawing	13.3 (8.4)	13.6	13.1	13.1 (3.1)	13.9	12.3	11.1 (2.4)	12.3	9.8	9.7 (2.3)	10.2	9.2	12.3 (3.2)	13.0	11.6

Formal Analysis

Minitab statistical software was used to conduct an Analysis of Variance (ANOVA) using the General Linear Model (GLM) with treatment and gender as main effects and fixed factors and subject as a random factor. For this mixed model, the main effects were analyzed both separately and in interaction. Before formal analysis was conducted, it was necessary to check the GLM assumptions for normally distributed data. For score sections S2, S3, and S6-S9, no analysis was conducted because all scores were equal within each section for all treatments and both genders. The scores from these sections were included in the sum reflected in S0, the total scores.

Checking the Model Assumptions. Minitab ANOVA GLM residual plots were used to check the linear model assumptions for the MMSE scores and times for which analysis was conducted. For each response variable, the probability plot is approximately linear, so it is reasonable to assume that the random errors follow a normal probability model. In addition, the plot of residuals versus fitted values indicates that the residuals are distributed fairly evenly above and below the zero line, supporting the assumption that the random errors have linearity and a mean of zero. The vertical spread of the residuals is fairly constant, allowing the assumption that the random errors in the model have constant variance. The assumptions about the random errors in the linear model were satisfied for all response variables for which analysis was conducted. Formal analysis ensued.

Analysis of Variance (ANOVA). The initial ANOVA considered all factors and interactions. If statistical reliability was indicated for any factor(s), the factors not showing statistical reliability ($p < .05$) were systematically eliminated from the model to reveal the final p-value(s). Where the treatment effect proved statistically reliable, Bonferroni 95% Confidence Intervals (CIs) were then calculated to identify the specific treatment pair combinations that were important. Recall that treatment encompasses both activity and respirator usage considerations. The treatments are R, at rest with no respirator; N, post-WAnT with no respirator; P, post-WAnT with an air-purifying respirator; and S, post-WAnT with an air-supplying respirator. The treatment pairs are N-P, N-R, N-S, P-R, P-S, and R-S.

The following sections summarize the results for each response variable that are detailed in Appendix E, Tables E1-E17. For statistically reliable results, effect size as indicated by omega squared (ω^2) is specified and graphs that illustrate the main effects, treatment and gender, are shown. Kirk (2007) considers effect size indicated by omega squared to be small if less than 0.06, medium if from 0.06 to under 0.14, and large if equal to or greater than 0.14.

Results for score response variables. The statistical results for the score response variables are summarized in this section. Only activity level showed selective statistical reliability regarding MMSE scores for S0 and S1. No changes and therefore no effect occurred for the following response variables: S2 orientation to place, S3 registration, S6 naming, S7 repetition, S8 comprehension, S9 reading, S10 writing, or S11 drawing. For these variables, no statistical analysis was conducted because all scores within each variable are the same for all treatments and genders. Where there is statistical reliability for treatment or gender, main effects plots are included to illustrate their effects. Where subject as a random factor is significant, this does not denote a predictive effect but rather shows that the variance of individual subject responses, is significant for the particular response variable. Thus, no illustrative plots are included for significant subject effects.

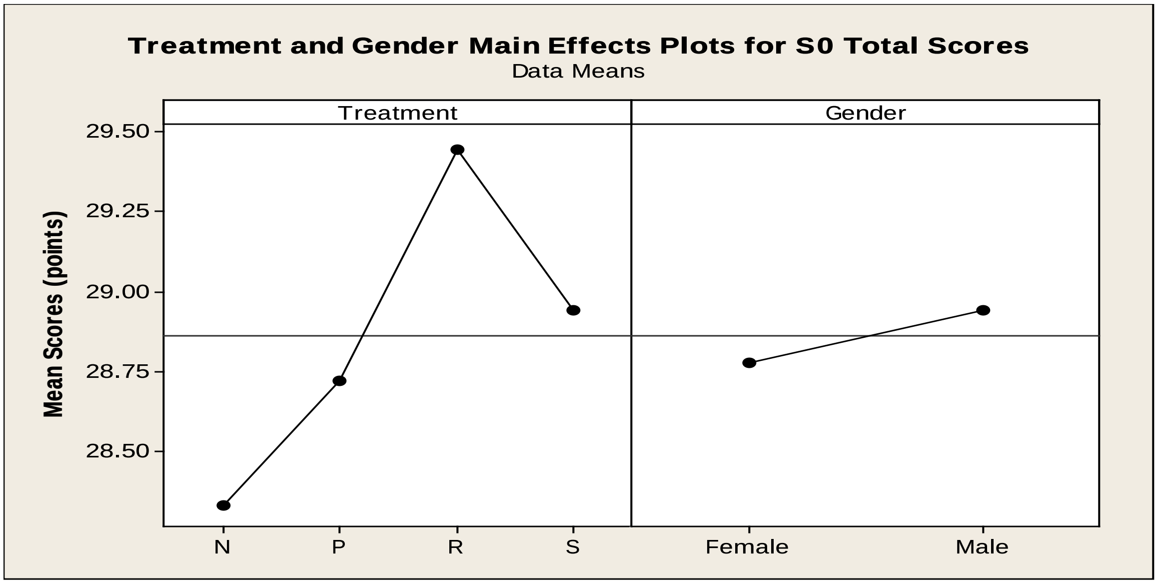
The statistically reliable effect of treatment on S0 total scores ($F_{3, 68} = 2.96$, $p = .038$, $\omega^2 = 0.07$) indicates that S0 total scores are significantly affected by treatment differences. Bonferroni 95% Confidence Interval (CI) calculations show significance for treatment pair N-R (CI = [0.1195, 2.103]), with the mean resting no respirator R score

(M = 29.4 points, SD = 0.6) significantly higher than the mean post-WAnT no respirator N score (M = 28.3 points, SD = 1.2).

No statistically reliable effects on S0 total scores were identified for gender ($F_{1, 48} = 0.28$, $p = .604$; female M = 28.8 points; male M = 28.9 points), or the treatment-gender interaction ($F_{3, 48} = 0.57$, $p = .638$), or subject ($F_{16, 48} = 1.52$, $p = .128$), indicating that S0 scores are not significantly affected by these factors. In summary, S0 total scores were significantly affected by treatment differences but not by gender differences, by treatment-gender interaction influences, or by variations in individual subject responses. Figure 3 illustrates the main effects for S0 total scores.

Figure 3

Treatment and Gender Main Effects Plots for S0 Total Scores

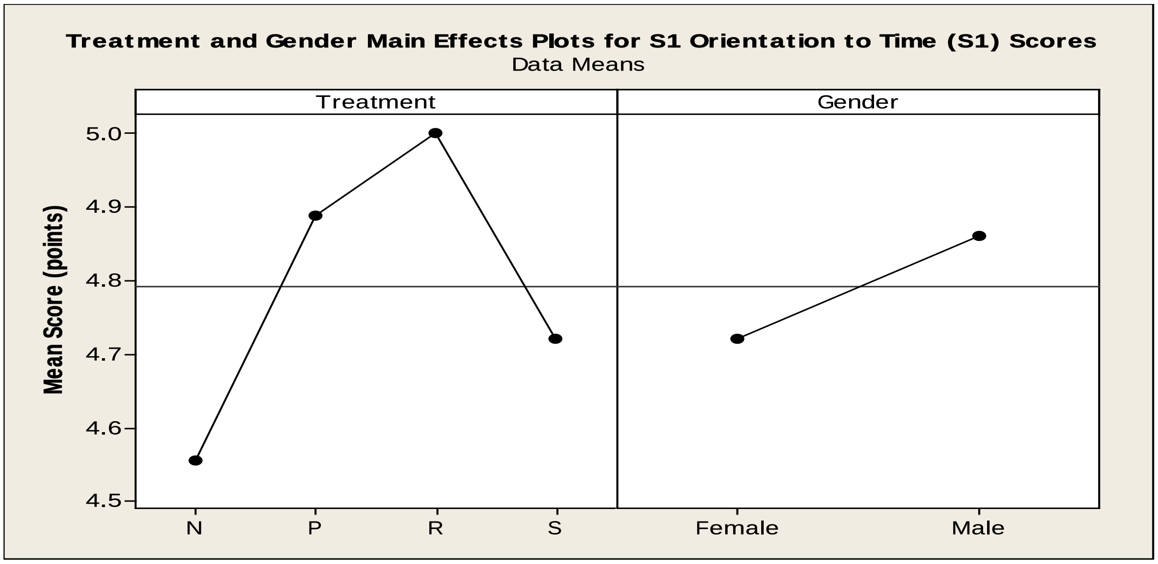


The statistically reliable effect of treatment on S1 orientation to time scores ($F_{3, 68} = 3.91$, $p = .012$, $\omega^2 = 0.11$) indicates that S1 orientation to time scores are significantly altered by treatment differences. Bonferroni 95% Confidence Interval (CI) calculations showed significance for treatment pair N-R (CI = [0.0666, 0.8223]), with the mean resting no respirator R score (*M* = 5.0 points, *SD* = 0.0) significantly higher than the mean post-WAnT no respirator N score (*M* = 4.6 points, *SD* = 0.5).

No statistically reliable effects on S1 orientation to time scores were identified for gender ($F_{1, 48}$ = 0.28, *p* = .176; female *M* = 4.7 points; male *M* = 4.9 points), the treatment-gender interaction ($F_{3, 48}$ = 0.72, *p* = .545), or subject ($F_{16, 51}$ = 1.00, *p* = .473), indicating that S1scores are not significantly affected by these factors. In summary, S1 orientation to time scores were significantly affected by treatment differences but not by gender differences, by treatment-gender interaction influences, or by variations in individual subject responses. Figure 4 illustrates the main effects for S1 orientation to time scores.

Figure 4

Treatment and Gender Main Effects Plots for S1 Orientation to Time Scores



No statistically reliable effects on S4 attention and calculation scores were identified for treatment ($F_{3, 48}$ = 1.90, *p* = .142), gender ($F_{1, 48}$ = 0.87, *p* = .365; female *M* = 4.2 points; male *M* = 4.4 points), the treatment-gender interaction ($F_{3, 48}$ = 0.06,

p = .979), or subject ($F_{16, 48}$ = 1.73, p = .074), indicating that S4 scores are not significantly affected by these factors. In summary, S4 attention and calculation scores were not significantly affected by treatment or gender differences, by treatment-gender interaction influences, or by variations in individual subject responses.

No statistically reliable effects on S5 recall scores were identified for treatment ($F_{3, 48}$ = 1.43, p = .245), gender ($F_{1, 48}$ = 1.96, p = .181; female M = 2.9 points; male M = 2.7 points), the treatment-gender interaction ($F_{3, 48}$ = 0.88, p = .458), or subject ($F_{16, 48}$ = 1.29, p = .240), indicating that S5 times are not significantly affected by these factors. In summary, S5 recall scores were not significantly affected by treatment or gender differences, treatment-gender interaction influences, or by variations in individual subject responses.

Results for time response variables. The following section summarizes the statistical results for each individual time variable. Activity level, respirator intervention, gender and individual subject response showed selective statistical reliability regarding MMSE times. Where statistical reliability occurred, graphs are included to illustrate the effects.

The statistically reliable effect of treatment on T0 total time ($F_{3, 51}$ = 21.95, p = .000, ω^2 = 0.28) indicates that T0 total times were significantly affected by treatment differences. Bonferroni 95% Confidence Interval (CI) calculations showed significance for the following treatment pairs:

- N-R (CI = [-27.00, -9.00]), with the mean resting no respirator R time (M = 109.8 seconds, SD = 12.2) significantly lower than the mean post-WAnT no respirator N time (M = 127.8 seconds, SD = 17.7);

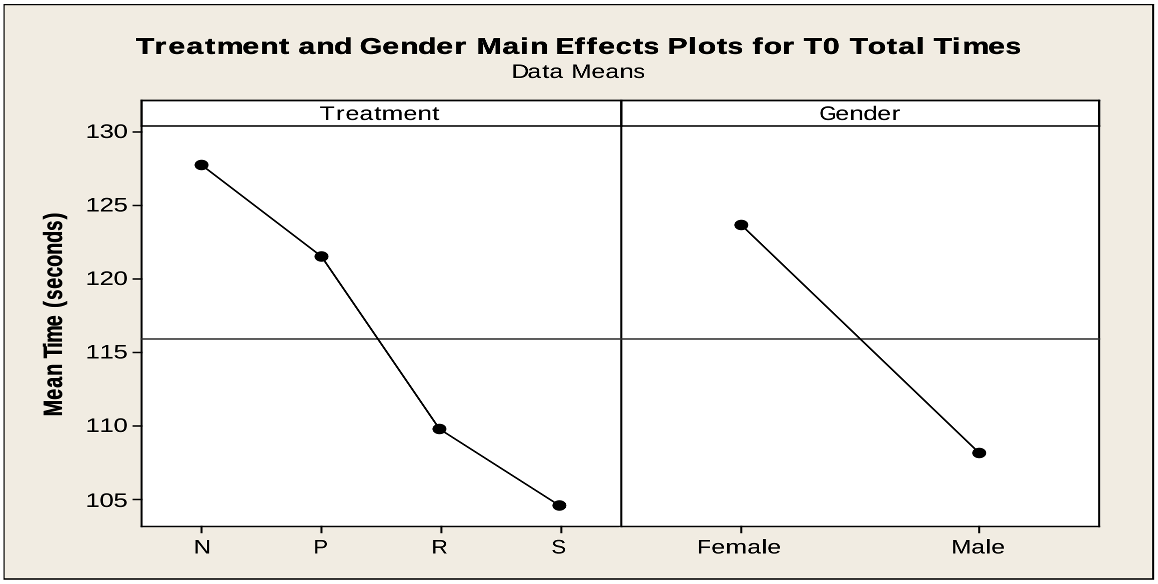
- N-S (CI = [-32.22, -14.22]), with the mean post-WAnT air-supplying respirator S time (*M* = 104.6 seconds, SD = 12.2) significantly lower than the mean post-WAnT no respirator N time (*M* = 127.8 seconds, *SD* = 17.7);
- P-R (CI = [-20.78, -2.778]), with the mean resting no respirator R time (*M* = 109.8 seconds, *SD* = 12.2) significantly lower than the mean post-WAnT air-purifying respirator P time (*M* = 121.6 seconds, *SD* = 15.3); and
- P-S (CI = [-26.00, -8.00]), with the mean post-WAnT air-purifying respirator P time (*M* = 121.6 seconds, *SD* = 15.3) significantly higher than the mean S time (*M* = 104.6 seconds, *SD* = 12.2).

Statistically reliable effects on T0 total time were also identified for gender ($F_{1, 51}$ = 13.64, p = .002, ω^2 = 0.21; female *M* = 123.7 seconds; male *M* = 108.2 seconds), indicating that gender differences are significant, with male total response times significantly lower than female; and for subject ($F_{16, 51}$ = 3.28, p = .001, ω^2 = 0.17), showing that individual subject response variance was significant for total times.

No statistically reliable effects on T0 total times were identified for the treatment-gender interaction ($F_{3, 48}$ = 1.74, p = .172). In summary, T0 total times were significantly affected by treatment, with significant differences between treatment pairs N-R, N-S, P-R, and P-S; by gender; with male times lower than female; and by variations in individual subject response; but were not influenced by treatment-gender interaction. Figure 5 illustrates the main effects for T0 total time.

Figure 5

Treatment and Gender Main Effects Plots for T0 Total Times



No statistically reliable effects on T1 orientation to time times were identified for treatment ($F_{3, 48} = 1.50$, $p = .227$), gender ($F_{1, 48} = 1.84$, $p = .194$; female $M = 13.5$ seconds; male $M = 12.6$ seconds), the treatment-gender interaction ($F_{3, 48} = 0.92$, $p = .439$), or subject ($F_{16, 48} = 1.34$, $p = .213$), indicating that T1 times are not significantly affected by these factors. In summary, T1 orientation to time times were not significantly affected by treatment or gender differences, by treatment-gender interaction influences, or by variations in individual subject responses.

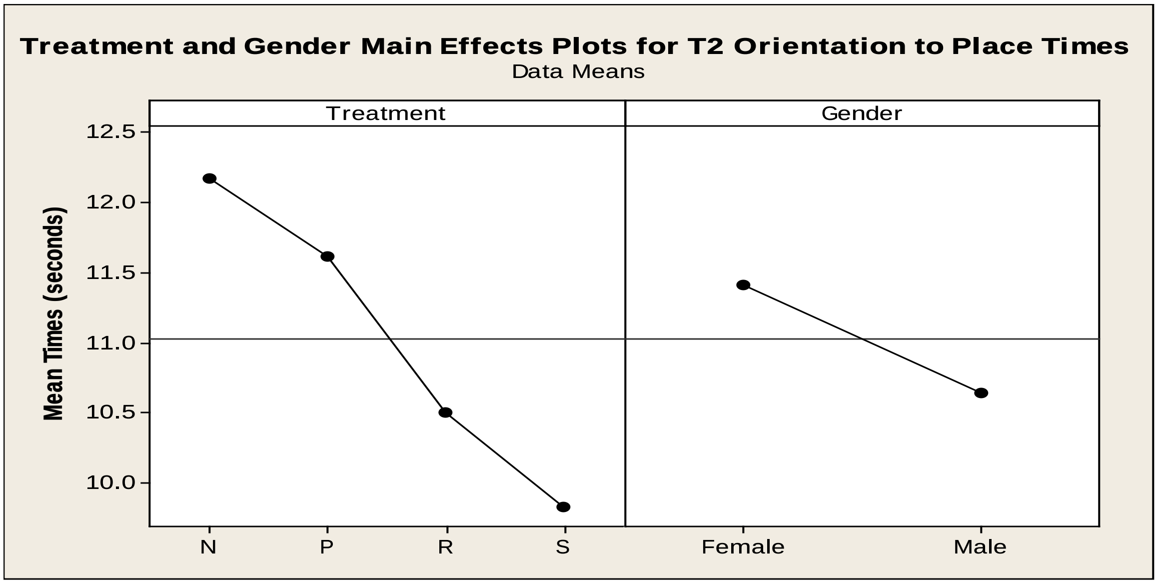
The statistically reliable effect of treatment on T2 orientation to place times ($F_{3, 51} = 6.90$, $p = .001$, $\omega^2 = 0.18$) indicates that T2 times significantly differed due to treatment. Bonferroni 95% Confidence Interval (CI) calculations showed significance for the following treatment pairs:

- N-R (CI = [-3.303, -0.307]), with the mean resting no respirator R time (*M* = 10.5 seconds, *SD* = 1.7) significantly lower than the mean post-WAnT no respirator N time (*M* = 12.2 seconds, *SD* = 2.3);
- N-S (CI = [-3.969, -0.6974]), with the mean post-WAnT air-supplying respirator S time (*M* = 9.8 seconds, *SD* = 1.6) significantly lower than the mean post-WAnT no respirator N time (*M* = 12.2 seconds, *SD* = 2.3); and
- P-S (CI = [-3.414, -0.1418]), with the mean post-WAnT air-purifying respirator P time (*M* = 11.6 seconds, *SD* = 1.5) significantly higher than the mean post-WAnT air-supplying respirator S time (*M* = 9.8 seconds, *SD* = 1.6).

No statistically reliable effects on T2 orientation to place times were identified for gender ($F_{1, 51} = 2.79$, $p = .115$; female *M* = 11.4 seconds; male *M* = 10.6 seconds), the treatment-gender interaction ($F_{3, 48} = 0.91$, $p = .442$), or subject ($F_{17, 51} = 1.49$, $p = .138$), indicating that T2 times are not significantly affected by these factors. In summary, T2 orientation to place times were significantly affected by treatment, with significant differences between treatment pairs N-R, N-S, and P-S; but not significantly affected by gender differences, the influence of treatment-gender interaction, or variations in individual subject responses. Figure 6 illustrates the main effects for T2 orientation to place times.

Figure 6

Treatment and Gender Main Effects Plots for T2 Orientation to Place Times

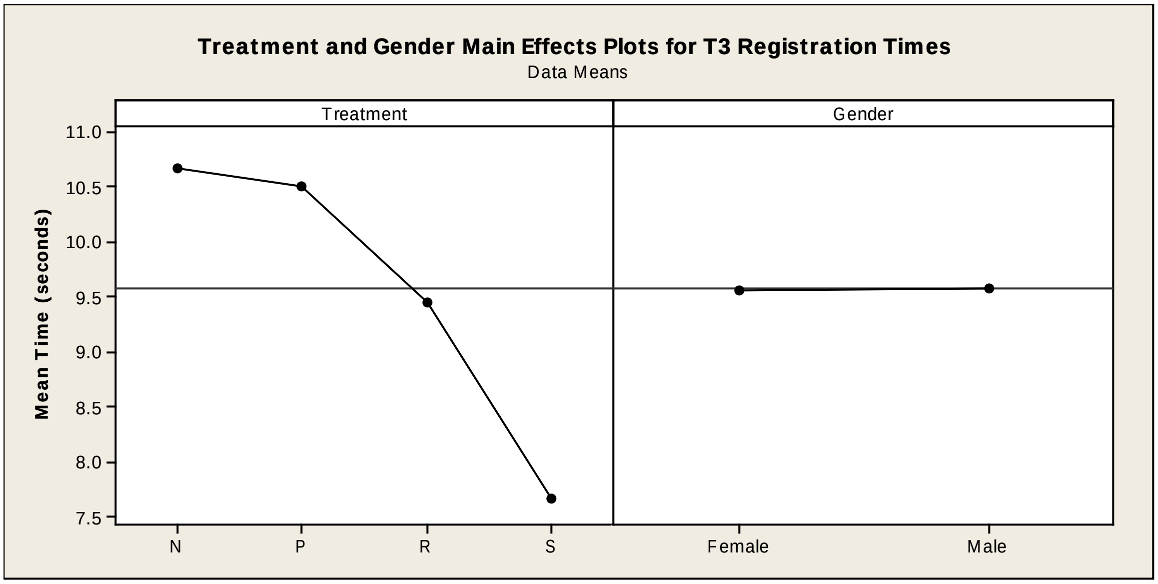


The statistically reliable effect of treatment on T3 registration times ($F_{3,\,68}$ = 3.29, p = .026, ω^2 = 0.09) indicates that T3 times were significantly affected by treatment differences. Bonferroni 95% Confidence Interval (CI) calculations showed significance for treatment pair N-S (CI = [-5.921, -0.07916]), with the mean post-WAnT air-supplying respirator S time (*M* = 7.7 seconds, *SD* = 1.2) significantly lower than the mean post-WAnT no respirator N time (*M* = 10.7 seconds, *SD* = 5.6).

No statistically reliable effects on T3 registration times were identified for gender ($F_{1,\,51}$ = 0.00, p = .970; female *M* = 9.6 seconds; male *M* = 9.6 seconds), the treatment-gender interaction ($F_{3,\,48}$ = 0.10, p = .961), or subject ($F_{17,\,51}$ = 0.82, p = .666), indicating that T3 times are not significantly affected by these factors. In summary, T3 registration times were significantly affected by treatment, with significant differences between treatment pair N-S; but not significantly affected by gender differences, by the influence of treatment-gender interaction, or by variations in individual subject responses. Figure 7 illustrates the main effects for T3 registration times.

Figure 7

Treatment and Gender Main Effects Plots for T3 Registration Times

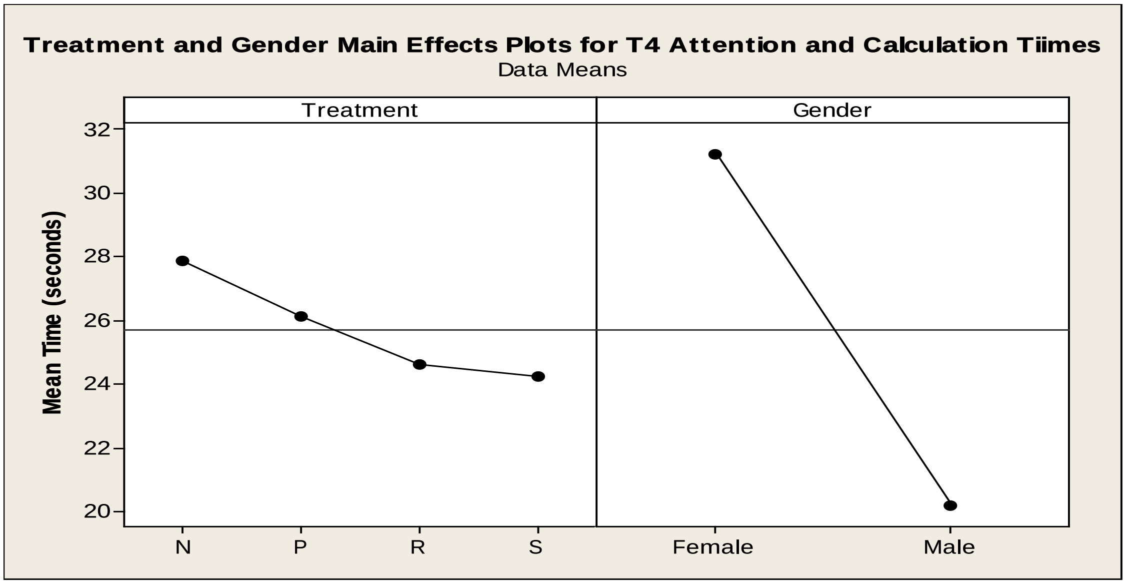


The statistically reliable effect of gender on T4 attention and calculation times ($F_{1, 48}$ = 23.80, p = .000, ω^2 = 0.35) indicates that T4 differences between males and females (female M = 31.2 seconds; male M = 20.2 seconds) are significant, with male completion times significantly shorter than females. The statistically reliable effect of subject ($F_{16, 48}$ = 2.11, p = .023, ω^2 = 0.13) shows that individual subject response variance for T4 is significant.

No statistically reliable effects on T4 attention and calculation times were identified for treatment ($F_{3, 48}$ = 1.15, p = .340) or the treatment-gender interaction ($F_{3, 48}$ = 0.48, p = .699) indicating that T4 times are not significantly affected by these factors. In summary, T4 attention and calculation times were significantly affected by gender differences and by variations in individual subject response but not by treatment differences or by the influence of treatment-gender interaction. Figure 8 illustrates main effects for T4 attention and calculation.

Figure 8

Treatment and Gender Main Effects Plots for T4 Attention and Calculation Times



No statistically reliable effects on T5 recall times were identified for treatment ($F_{3, 48}$ = 2.17, p = .104), gender ($F_{1, 48}$ = 0.21, p = .650; female M = 5.1 seconds; male M = 5.3 seconds), the treatment-gender interaction ($F_{3, 48}$ = 0.50, p = .685), or subject ($F_{16, 48}$ = 1.06, p = .415), indicating that T5 times are not significantly affected by these factors. In summary, T5 recall times were not significantly affected by treatment or gender differences, the influence of treatment-gender interaction, or variations in individual subject responses.

No statistically reliable effects on T6 naming times were identified for treatment ($F_{3, 48}$ = 1.18, p = .329), gender ($F_{1, 48}$ = 0.01, p = .923), the treatment-gender interaction ($F_{3, 48}$ = 1.80, p = .160), or subject ($\mathrm{F}_{16, 48}$ = 1.06, p = .419), indicating that T6 times are not significantly affected by these factors. In summary, T6 naming times were not significantly affected by treatment or gender differences, the influence of treatment-gender interaction, or variations in individual subject responses.

No statistically reliable effects on T7 repetition times were identified for treatment ($F_{3, 48} = 2.68$, $p = .057$), gender ($F_{1, 48} = 0.28$, $p = .602$; female $M = 6.6$ seconds; male $M = 6.4$ seconds), the treatment-gender interaction ($F_{3, 48} = 0.78$, $p = .512$), or subject ($F_{16, 48} = 1.31$, $p = .228$), indicating that T7 times are not significantly affected by these factors. In summary, T7 repetition times were not significantly affected by treatment or gender differences, the influence of treatment-gender interaction, or variations in individual subject responses.

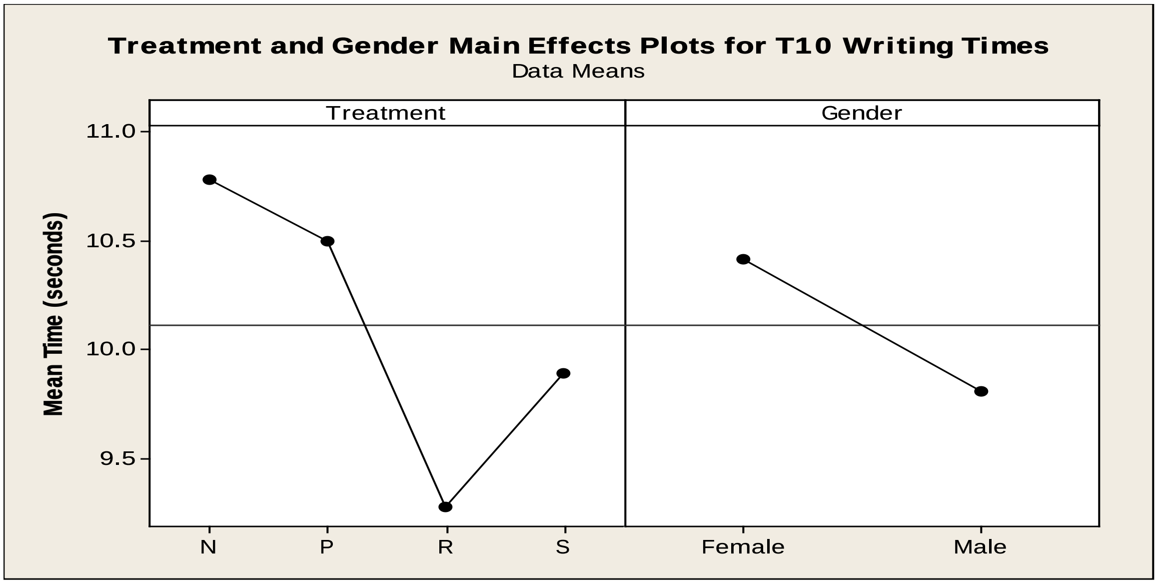
No statistically reliable effects on T8 comprehension times were identified for treatment ($F_{3, 48} = 2.57$, $p = .065$), gender ($F_{1, 48} = 2.46$, $p = .137$; female $M = 13.6$ seconds; male $M = 12.3$ seconds), the treatment-gender interaction ($F_{3, 48} = 0.49$, $p = .694$), or subject ($F_{16, 48} = 0.71$, $p = .774$), indicating that T8 times are not significantly affected by these factors. In summary, T8 comprehension times were not significantly affected by treatment or gender differences, the influence of treatment-gender interaction, or variations in individual subject responses.

No statistically reliable effects on T9 comprehension times were identified for treatment ($F_{3, 48} = 1.11$, $p = .354$), gender ($F_{1, 48} = 1.11$, $p = .309$; female $M = 4.0$ seconds; male $M = 4.6$ seconds), the treatment-gender interaction ($F_{3, 48} = 1.68$, $p = .183$), or subject ($F_{16, 48} = 1.13$, $p = .360$), indicating that T9 times are not significantly affected by these factors. In summary, T9 reading times were not significantly affected by treatment or gender differences, the influence of treatment-gender interaction, or variations in individual subject responses.

The statistically reliable effect of subject on T10 writing times ($F_{16, 51} = 2.15$, $p = .020$, $\omega^2 = 0.20$) indicates that variations in individual subject response are significantly different for T10. No statistically reliable effects on writing were identified for treatment ($F_{3, 51} = 1.43$, $p = .244$), gender ($F_{1, 51} = 0.56$, $p = .465$; female $M = 10.4$ seconds; male $M = 9.8$ seconds), or the treatment-gender interaction ($F_{3, 48} = 2.73$, $p = .054$) indicating that T10 times are not significantly affected by these factors. In summary, T10 writing times were significantly affected by variations in individual subject responses but not by treatment or gender differences, or by the influence of treatment-gender interaction. Figure 9 illustrates the main effects for T10.

Figure 9

Treatment and Gender Main Effects Plots for T10 Writing Times



The statistically reliable effect of treatment on T11 drawing times ($F_{3, 51} = 5.85$, $p = .002$, $\omega^2 = 0.14$) indicates that treatment differences significantly affected T11. Bonferroni 95% Confidence Interval (CI) calculations showed significance for the following treatment pairs:

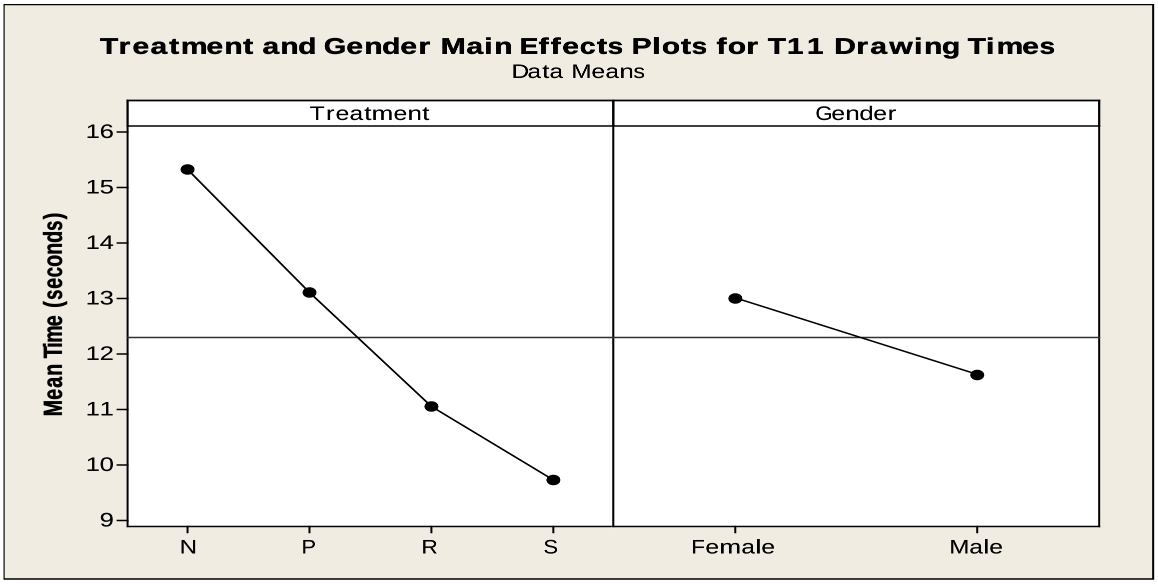
- N-R (CI = [-8.217, -0.339]), with the mean resting no respirator R time (M = 11.1 seconds, SD = 2.4) significantly lower than the mean post-WAnT no respirator N time (M = 15.3 seconds, SD = 8.4);
- N-S (CI = [-32.22, -14.22]), with the mean post-WAnT air-supplying respirator S time (M = 9.7 seconds, SD = 2.5) significantly lower than the mean post-WAnT no respirator N time (M = 15.3 seconds, SD = 8.4).

The statistically reliable effect of subject ($F_{17, 51} = 1.97$, $p = .033$, $\omega^2 = 0.16$) on T11 drawing times shows that individual subject response variance is significant.

No statistically reliable effects on T11 drawing times were identified for gender ($F_{1, 51} = 0.95$, $p = .344$; female M = 13.0 seconds; male M = 11.6 seconds) or the treatment-gender interaction ($F_{3, 48} = 0.19$, $p = .904$) indicating that T11 times are not significantly affected by these factors. In summary, T11 drawing times were significantly affected by treatment differences, with significant differences between treatment pairs N-R and N-S; and by variations in individual subject response, but not by gender differences or by the influence of treatment-gender interaction. Figure 10 illustrates the main effects for T11 drawing.

Figure 10

Treatment and Gender Main Effects Plots for T11 Drawing Times



The details of statistical analysis for all variables are tabulated in Appendix E. These results are also referenced in the next section, in which the research questions are answered and the null hypothesis test results are reported.

Research Questions Answered

The objectives of this study and analysis include answering the general research questions posed. These questions are multifaceted, as are the hypotheses, inclusive of the total and sectional MMSE scores and times, each of which has individual results. With analysis completed and statistical reliability determined, the research questions are now answered. Included with each question are the null hypotheses testing results upon which these answers are based.

Research Question 1 – Activity Effects

Research question 1 asks whether the cognitive function of healthy, active college students will vary significantly due to activity level differences. The answer is a qualified yes. Selective statistical reliability was shown for some but not all score and time response variables between resting treatment R and post-WAnT treatments N, P, or S. These variables are S0 total scores (R > N), S1 orientation to time scores (R > N), T0 total times (N > R, P > R), T2 orientation to place times (N > R), and T11 drawing times (N > R). This question is addressed in null hypotheses 1 for scores and 2 for times.

Null Hypothesis 1. Null Hypothesis 1 (H_0 1) states that activity differences will not produce a statistically reliable effect on total or sectional MMSE scores. This hypothesis compares mean scores from the resting no-respirator treatment (R) to the post-WAnT activity treatments (N, P, and S). As shown in Table 4, statistical reliability was attained for score response variables S0 total and S1 orientation to time.

Table 4

Null Hypothesis 1 – Activity Differences for Scores - Statistically Reliable Responses

Dependent Variable	**Source**	**DF**	***F***	***p***	**Effect Size (ω^2)**
S0 Total	Treatment R>N	3	2.96	.038	0.07
S1 Orientation to time	Treatment R>N	3	3.91	.012	0.11

- ***Reject H_0 1 for S0.*** There is a statistically reliable difference (*p* = .038) in S0 total scores with regard to treatment. The effect size is medium (ω^2 = 0.07). Further analysis with Bonferroni 95% CIs to pinpoint the important treatment differences revealed significant differences between treatment pair R-N (R > N, CI = [0.1195, 2.103]) that compares the no-activity treatment (R) to a post-WAnT treatment (N, P, and S).
- ***Reject H_0 1 for S1.*** There is a statistically reliable difference (*p* = .012) in S1 orientation to time scores with regard to treatment. The effect size is medium (ω^2 = 0.11). Further analysis with Bonferroni Confidence Intervals (CI) to pinpoint the

important treatment differences revealed significant differences between treatment pair R-N (R > N, CI = [0.0666, 0.8223]) that compares the no-activity treatment (R) to a post-WAnT treatment (N, P, and S).

- ***Fail to reject H_0 1 for S4 and S5.*** There is not a statistically reliable difference in the following score response variables due to activity changes.
  - S4 attention and calculation (*p* = .142)
  - S5 recall (*p* = .245)

Null Hypothesis 2

Null Hypothesis 2 (H_0 2) states that activity differences will not produce a statistically reliable effect on total or sectional MMSE times. This hypothesis compares mean times from the resting no-respirator treatment (R) to the post-WAnT activity treatments (N, P, and S). As show in Table 5, statistical reliability was attained for time response variables T0 total, T2 orientation to place, and T11 drawing.

Table 5

Null Hypothesis 2 – Activity Differences for Times - Statistically Reliable Responses

Dependent Variable	**Source**	**DF**	***F***	***p***	**Effect Size (ω^2)**
T0 Total	Treatment N>R, P>R	3	21.04	.000	0.28
T2 Orientation to place	Treatment N>R	3	6.9	.001	0.18
T11 Drawing	Treatment N>R	3	5.85	.002	0.14

- ***Reject H_0 2 for T0.*** There is a statistically reliable difference (*p* = .000) in T0 total times with regard to treatment. The effect size is large ($\omega^2 = 0.28$). Further analysis with Bonferroni 95% CIs to pinpoint the important treatment differences revealed significant differences between the following treatment pairs that compare the no-activity treatment (R) to a post-WAnT treatment (N, P, and S).

  - N > R CI = [-27.00, -9.00]
  - P > R CI = [-20.78, -2.778]

- ***Reject H_0 2 for T2.*** There is a statistically reliable difference (p = .001) in T2 orientation to place times with regard to treatment. The effect size is large (ω^2 = 0.18). Further analysis with Bonferroni 95% CIs to pinpoint the important treatment differences revealed significant difference between the following N > R treatment pair (CI = [-3.303, -0.0307]) that compares the no-activity treatment (R) to a post-WAnT treatment (N, P, and S).
- ***Reject H_0 2 for T11.*** There is a statistically reliable difference (*p* = .002) in T11 drawing times with regard to treatment. The effect size is large (ω^2 = 0.14). Further analysis with Bonferroni 95% CIs to pinpoint the important treatment differences revealed significant difference between treatment pair N-R , (N > R, CI = [-8.217, -0.339]) that compares the no-activity treatment (R) to a post-WAnT treatment (N, P, and S).
- ***Fail to reject H_0 2 for T1 and T3-T10.*** There is not a statistically reliable difference in the following time response variables due to activity differences.
  - T1 orientation to time (*p* = .227)
  - T3 registration (*p* = .026; no significant CI that included R)
  - T4 attention and calculation (*p* = .340)
  - T5 recall (*p* = .104),
  - T6 naming (*p* = .329)
  - T7 repetition (*p* = .057)
  - T8 comprehension (*p* = .065)
  - T9 reading (*p* = .354)
  - T10 drawing (*p* = .244)

Research Question 2 – Respirator Wear Effects

Research question 2 asks whether the cognitive function of healthy, active college students measured after maximal exertion will vary significantly due to respirator usage differences. The answer is no for scores but a qualified yes for times. Selective statistical reliability was found for some but not all time response variables but no score response variables between N, S, and P treatment pairs. These variables are T0 total times (N > S), T2 orientation to place times (N > S, P > S), T3 registration times (N > S) and T11 drawing times (N > S). This question is addressed in null hypotheses 3 for scores and 4 for times.

Null Hypothesis 3. Null Hypothesis 3 (H_0 3) states that respirator usage differences will not produce a statistically reliable effect on total or sectional MMSE scores. This hypothesis compares mean scores from the post-WAnT treatments (N, P, and S).

- ***Fail to reject H_0 3 for S0, S1, S4 and S5 scores.*** There is not a statistically reliable difference in the following score response variables due to respirator usage differences.
  - S0 total score (*p* = .030, no significant CI for N, P, S comparisons)
  - S1 orientation to time (*p* = .012, no significant CI for N, P, S comparisons)
  - S4 attention and calculation (*p* = .142)
  - S5 recall (*p* = .245)

Null Hypothesis 4. Null Hypothesis 4 (H_0 4) states that respirator usage differences will not produce a statistically reliable effect on total or sectional MMSE times. This hypothesis compares mean times from the post-WAnT activity treatments (N, P, and S). As shown in Table 6, statistical reliability was attained for time response variables T0 total, T2 orientation to place, T3 registration, and T11 drawing.

Table 6

Null Hypothesis 4 – Respirator Differences for Times - Statistically Reliable Responses

Dependent Variable	**Source**	**DF**	***F***	***p***	**Effect Size (ω^2)**
T0 Total	Treatment N>S, P>S	3	21.04	.000	0.28
T2 Orientation to place	Treatment N>S, P>S	3	6.9	.001	0.18
T3 Registration	Treatment N>S	3	3.29	.026	0.09
T11 Drawing	Treatment N>S	3	5.85	.002	0.14

- ***Reject H_0 4 for T0.*** There is a statistically reliable difference (p = .000) in T0 total times with regard to treatment. The effect size is large (ω^2 = 0.28). Further analysis with Bonferroni 95% CIs to pinpoint the important treatment differences revealed significant differences between the following treatment pairs that compare post-WAnT respirator usage (N, P, and S).
  - N > S CI = [-32.22, -14.22]
  - P > S CI = [-26.00, -8.00]
- ***Reject H_0 4 for T2.*** There is a statistically reliable difference (p = .001) in T2 orientation to place times with regard to treatment. The effect size is large (ω^2 = 0.18). Further analysis with Bonferroni 95% CIs to pinpoint the important treatment differences revealed significant differences between the following treatment pairs that compare post-WAnT respirator usage (N, P, and S).
  - N > S CI = [-3.969, -0.6974]
  - P > S CI = [-3.414, -0.1418]

- ***Reject H_0 4 for T3.*** There is a statistically reliable difference ($p = .026$) in T3 registration times with regard to treatment. The effect size is medium ($\omega^2 = 0.09$). Further analysis with Bonferroni 95% CIs to pinpoint the important treatment differences revealed significant differences between treatment pair N-S (N > S, CI = [-5.921, -0.07916]) that compares post-WAnT respirator usage (N, P, and S).
- ***Reject H_0 4 for T11.*** There is a statistically reliable difference ($p = .002$) in T11 drawing times with regard to treatment. The effect size is large ($\omega^2 = 0.14$). Further analysis with Bonferroni 95% CIs to pinpoint the important treatment differences revealed significant difference between treatment pair N-S (N > S, CI = [-9.550, -1.672]) that compares post-WAnT respirator usage (N, P, and S).
- ***Fail to reject H_0 4 for T1 and T4-T10.*** There is not a statistically reliable difference in the following time response variables due to post-WAnT respirator usage differences.
    - T1 orientation to time ($p = .227$)
    - T4 attention and calculation ($p = .340$)
    - T5 recall ($p = .104$),
    - T6 naming ($p = .329$)
    - T7 repetition ($p = .057$),
    - T8 comprehension ($p = .065$)
    - T9 reading ($p = .354$)
    - T10 writing ($p = .244$)

Research Question 3 – Gender Differences

Research question 3 asks whether the cognitive function of healthy, active college males and females will vary significantly from one another due to activity level or respirator usage differences. The answer is no for scores but a qualified yes for times. Selective statistical reliability was found for some but not all time response variables but no score response variables between females (F) and males (M). These variables are T0 total times (F > M) and T4 attention and calculation times (F > M). This question is addressed in null hypotheses 5 for scores and 6 for times.

Null Hypothesis 5. Null Hypothesis 5 (H_0 5) states that gender differences will not produce a statistically reliable effect on total or sectional MMSE scores. This hypothesis compares mean male scores to mean female scores. Statistical reliability was not attained for any score response variables for which analysis was conducted.

- ***Fail to reject H_0 5 for S0, S1, S4, and S5.*** There is not a statistically reliable difference in the following score response variables due to gender differences.
  - S0 total time (*p* = .365)
  - S1 orientation to time (*p* = .176)
  - S4 attention and calculation (*p* = .363)
  - S5 recall (*p* = .181)

Null Hypothesis 6. Null Hypothesis 6 (H_0 6) states that gender differences will not produce a statistically reliable effect on total or sectional MMSE times. This hypothesis compares mean male times to mean female times. As show in Table 7, statistical reliability was attained for time response variables T0 total and T4 attention and calculation.

Table 7.

Null Hypothesis 6 – Gender Differences for Time - Statistically Reliable Responses

Dependent Variable	**Source**	**DF**	***F***	***p***	**Effect Size (ω^2)**
T0 Total	Gender F>M	1	13.64	.002	0.21
T4 Attention and calculation	Gender F>M	1	23.80	.000	0.35

- ***Reject H_0 6 for T0 and T4.*** There is a statistically reliable difference in the following time response variables due to gender differences.
    - T0 total times (p = .002) F > M. The effect size is large ($\omega^2 = 0.21$).
    - T4 attention and calculation times (p = .000) F > M. The effect size is large ($\omega^2 = 0.35$).
- ***Fail to reject H_0 6 for T1, T2, T3 and T5-T11.*** There is not a statistically reliable difference in the following time response variables due to gender differences.
    - T1 orientation to time (p = .194)
    - T2 orientation to place (p = .115)
    - T3 registration (p = .970)
    - T5 recall (p = .650)
    - T6 naming (p = .923)
    - T7 repetition (p = .602)
    - T8 comprehension (p = .137)
    - T9 reading (p = .309)
    - T10 writing (p = .465)
    - T11 drawing (p = .344)

Research Question 4 – Interactive Effects

Research question 4 asks whether the cognitive function of healthy, active college students vary significantly due to the interaction of treatment (activity intensity, respirator usage) and gender. This question is addressed in null hypotheses 7 for scores and 8 for times. The answer is no on all counts—the main effects interaction showed no statistical reliability for total or sectional MMSE score or time response variables.

Null Hypothesis 7. Null Hypothesis 7 (H_0 7) states that gender and treatment in interaction will not produce a statistically reliable effect on total or sectional MMSE scores. This hypothesis identifies whether the effects due to treatment and gender together are additive or influence one another.

- ***Fail to reject H_0 7 for S0, S1, S4, and S5.*** There is not a statistically reliable difference in the following score response variables due an interaction between treatment and gender.
    - S0 total (*p* = .558)
    - S1 orientation to time (*p* = .545)
    - S4 attention and calculation (*p* = .979)
    - S5 recall (*p* = .458)

Null Hypothesis 8. Null Hypothesis 8 (H_0 8) states that gender and treatment in interaction will not produce a statistically reliable effect on total or sectional MMSE times. This hypothesis identifies whether the effects due to treatment and gender together are additive or influence one another.

- ***Fail to reject H_0 8 for T0-T11.*** There is not a statistically reliable difference in the following time response variables due an interaction between treatment and gender.
    - T0 total (*p* = .558)
    - T1 orientation to time (*p* = .439)
    - T2 orientation to place (*p* = .442)
    - T3 registration (*p* = .961)
    - T4 attention and calculation (*p* = .699)
    - T5 recall (*p* = .685)
    - T6 naming (*p* = .160)
    - T7 repetition (*p* = .512)
    - T8 comprehension (*p* = .694)
    - T9 reading (*p* = .183)
    - T10 writing (*p* = .054)
    - T11 drawing (*p* = .904)

Research Question 5 – Individual Subject Response Variance

Research question 5 asks whether there will be significant variance in cognitive function measurements due to individual subject response differences. The answer is no for scores but a qualified yes for times. Selective importance was found for some but not all time response variables but no score response variables in individual subject responses. These variables are T0 total times, T4 attention and calculation times, T10 writing times and T11 drawing times. This question is addressed in null hypotheses 9 for scores and 10 for times.

Null Hypothesis 9. Null Hypothesis 9 (H_0 9) states that variance in individual subject response measurements will not produce a statistically reliable effect on total or sectional MMSE scores. This hypothesis compares the variances of individual subject scores for each response variable rather than the mean scores of all subject responses for each predictor variable.

- ***Fail to reject H_0 9 for S0, S1, S4, and S5.*** Variance in individual subject response measurements did not produce a statistically reliable effect on the following score response variables.
  - S0 total (p = .283)
  - S1 orientation to time (p = .456)
  - S4 attention and calculation (p = .074)
  - S5 recall (p = .240)

Null Hypothesis 10. Null Hypothesis 10 (H_0 10) states that variance in individual subject response measurements will not produce a statistically reliable effect on total or sectional MMSE times. This hypothesis compares the variances of individual subject times for each response variable rather than the mean times of all subject responses for each predictor variable. As shown in Table 8, statistical reliability was attained for time response variables T0 total, T4 attention and calculation, T10 writing, and T11 drawing.

Table 8.

Null Hypothesis 10 – Subject Differences for Times - Statistically Reliable Responses

Dependent Variable	Source	DF	*F*	*p*	Effect Size (ω^2)
T0 Total	Subject (Gender)	16	3.28	.001	0.17
T4 Attention and calculation	Subject (Gender)	16	2.11	.023	0.13
T10 Writing	Subject (Gender)	16	2.15	.020	0.20
T11 Drawing	Subject (Gender)	16	1.97	.034	0.16

- ***Reject H_0 10 for T0, T4, T10, and T11.*** Variance in individual subject response measurements produced a statistically reliable effect on the following time response variables.
  - T0 total (p = .001). The effect size is large (ω^2 = 0.17).
  - T4 attention and calculation (p = .023). The effect size is medium (ω^2 = 0.13).
  - T10 writing (p = .020). The effect size is large (ω^2 = 0.20).
  - T11 drawing (p = .034). The effect size is large (ω^2 = 0.16).
- ***Fail to reject H_0 10 for T1-T3 and T5-T9.*** Variance in individual subject response measurements did not produce a statistically reliable effect on the following time response variables.
  - T1 orientation to time (p = .213)
  - T2 orientation to place (p = .208)
  - T3 registration (p = .606)
  - T5 recall (p = .415)
  - T6 naming (p = .419)
  - T7 repetition (p = .228)
  - T8 comprehension (p = .774)
  - T9 reading (p = .360)

Null hypotheses testing was complex due to the large number of response variables and the inclusive nature of the research questions and hypotheses. Given the results of the null hypotheses testing, only null hypotheses 7 and 8 regarding the interactive effect of treatment and gender have unqualified results. Because there were no significant interactive effects on any score or time variables, these null hypotheses are not rejected.

Summary of Chapter Four

In Chapter 4, data were reported and summarized descriptively to provide a foundational perspective and a preliminary look at trends, after which formal statistical analysis was reported. Where relevant, the statistically reliable results of analysis for the main effects and individual subject response were presented in tabular form. All results were presented in the context of the research questions and the results of the null hypotheses testing.

In the final chapter, the results and trends that emerged from this study, along with are compared, contrasted, and discussed in both theoretical and practical terms. Recommendations are put forth to regulatory agencies, employers, and researchers to consider this and similar research when considering policy change and pathways for more in-depth description of the complex interaction of cognitive function, activity, and respirator wear.

CHAPTER FIVE

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

Introduction

The relatively sparse line of research that integrates respirator wear, physical activity, and cognitive change will benefit both practically and theoretically from the results and observations of this study. The transient changes in cognitive function that were identified contribute a distinct thread of information linking the networks of knowledge about physical activity, respirator wear, gender differences, and cognitive function, and make a unique contribution to these research areas. These results are important when considering the singular or dual occurrence of physical activity and respirator wear in the workplace, where worker safety and health are paramount and occupational stressors such as intense exertion and respirator wear are common.

Reflection on these results and on the study as a whole generates a collection of observations and conclusions. The integration of activity level and respirator usage in each of the four treatments provides an assortment of situations in which to study cognitive function related to both activity alone and to activity and respirator-wear combinations. Even though 18 active, healthy young college students do not comprise a random sample of any general population, results and observations from this purposeful sample should be considered carefully as possible indicators of similar and even greater effects in older, less healthy populations. The equal representation of males and females allowed comparison of gender differences, some of which were significant— an important research consideration that is often overlooked.

The cognitive assessment was the Mini Mental State Examination (MMSE), a brief assessment of cognitive function. Each of the four treatments included an activity component and a respirator usage component that allowed for evaluation of a variety of stressor groupings. Activity-related effects were assessed by comparing the resting no-respirator treatment R to the data from the N, P, and S treatments, which were collected immediately after performance of the rigorous Wingate Anaerobic Test (WAnT), a 30-second maximal exertion cycle ergometry protocol. Respirator usage effects were assessed by comparison of the three post-WAnt treatments—wearing no respirator N, wearing an air-purifying respirator P, and wearing an air-supplying respirator S.

Together, the components of the MMSE comprise a comprehensive view of cognition, with each of the 11 sections focusing on a particular facet of cognitive and/or psychomotor function. The MMSE indicates cognitive status at the time of the assessment (Folstein, Folstein, & McHugh, 1975). Score and time data collected from administration of the MMSE immediately after each of the three WAnT- respirator usage treatments (N, P, and S) and at the fourth no respirator or activity treatment R were analyzed for statistically reliable differences. Neither use of the MMSE to compare short-term changes in cognitive function in normal individuals nor timing the administration of the test to compare response time differences had been previously conducted. This extended application of the widely used test is of interest pertaining to expanding its capabilities and usage, and contributes to its refinement and validation for broader use.

The total and sectional MMSE test scores and times, the dependent or response variables, are designated by a letter-number combination that includes either the letter S for scores or T for times, followed by a number corresponding to the appropriate section number on the MMSE score form in Appendix D. Scores are S0-S11 and times are T0-T11, with S0 and T0 being total scores and times and S1-11 and T1-11 being the sectional scores and times. Each subject was scored and timed as they answered or performed the required tasks described below. The score and time codes and the point value of each are shown in parentheses.

1. *Orientation to time* (S1, T1) required saying the day, date, and season to assess awareness of one's temporal point of reference. (5 points)
2. *Orientation to place* (S2, T2) required saying the specific location, city, and state to assess awareness of one's physical point of reference. (5 points)
3. *Registration* (S3, T3) required repetition of three unrelated words verbalized by the tester to assess immediate recall. For this study, these words were changed for each treatment. (3 points)
4. *Attention and calculation* (S4, T4) required verbalizing the answers of mental serial subtraction of 7 from the starting number to assess calculation ability. For this study, the numeric starting point was changed for each treatment. (5 points)
5. *Recall* (S5, T5) required recollection of previously repeated words (from #3) to assess short term memory. (3 points)
6. *Naming* (S6, T6) required recognition of and naming common objects held up by tester. For this study, different random objects such as a pen or a watch were used for each treatment. (2 points)
7. *Repetition* (S7, T7) required repeating the phrase "no ifs, ands, or buts" after verbalized by tester. (1 points)
8. *Comprehension* (S8, T8) required performing the three-stage command "Pick up this paper in your (left or right) hand, fold it in half, and set it on the table" after verbalized by tester to assess understanding and sequential task performance. (3 points)

9. *Reading* (S9, T9) required silently reading “Close your eyes” on a piece of paper and doing so to assess understanding. (1 points)
10. *Writing* (S10, T10) required writing a sentence on paper. (1 points)
11. *Drawing* (S11, T11) required being shown a picture of two intersecting pentagons and correctly reproducing the design on paper. (1 points)

The total MMSE scores and times are the sum of the 11 sectional scores and times for each treatment. The total possible score is 30 points. The times are in seconds, with zero minimum and no maximum time limit. See Appendix C for the MMSE score sheet.

To disclose important relationships between and among treatments (activity level, respirator usage), gender, the treatment-gender interaction, and individual subject responses, the MMSE scores and times were analyzed for statistical reliability ($p = .05$) using a two-way ANOVA and calculation of Bonferroni 95% Confidence Intervals where treatment was statistically reliable. In addition to statistical reliability, both direction and size of effect are important for interpretation of the results of this study. Higher MMSE scores and shorter MMSE times are presumed to indicate cognitive improvement or a positive effect consistent with clearer thinking and faster thought or reaction time. Conversely, lower MMSE scores and greater MMSE times are considered detrimental or negative effects that denote impaired or lower thought clarity or response time. Effect size, or the degree of cause-effect association between the independent and dependent variables, is indicated by omega squared (ω^2) for statistically reliable results. Kirk (2007) considers effect size indicated by omega squared to be small if less than 0.06, medium if from 0.06 to under 0.14, and large if equal to or greater than 0.14.

Both positive and negative effects occurred in this research, some statistically reliable and others of lesser magnitude. The broad conclusion that cognitive function is selectively altered by these variables is moderated by the fact that the effects of the predictor variables on the response variables are random, varied, sometimes incongruent, and often surprising. In the following sections, the problem and research questions are restated, after which the findings are summarized and discussed.

Restatement of the Problem

Respirator wear and hard physical labor are common occupational stressors, either alone or in combination (Sharkey & Davis, 2008). Thoroughly screening workers for ability to wear a respirator and perform hard work would not only inform the employer and worker of potential problems but also educate the worker about the requirements and expectations of the job. The current OSHA respiratory protection standard requires workers that wear respirators to be medically cleared through self-completion of a questionnaire and requires no face-to-face interaction or evaluation of ability to wear a respirator and perform hard work. Adverse effects from either or both of these stressors may physiologically and psychologically overload the worker and impair clarity and speed of thought and action, thus endangering the worker and perhaps other workers and the environment. Strengthening existing federal regulation of respirator wear to include face-to-face evaluation of worker health and fitness, expected work intensity, and respirator selection will insure that workers wearing a respirator are aware of and can safely endure the accompanying physiological and psychological stress.

Research Questions

In order to more comprehensively describe transient cognitive differences that occur as a result of activity level, respirator usage, gender, and individual subject variance, the total and 11 sectional MMSE scores and times were analyzed for statistically reliable differences ($p < .05$) with regard to these factors. The following five research questions were explored through testing of ten related null hypotheses—two for each question, one for scores and one for times.

Research Question 1 – Activity Effects

Will the cognitive function of healthy, active college students vary significantly due to activity level differences?

Research Question 2 – Respirator Wear Effects

Will the cognitive function of healthy, active college students measured after maximal exertion vary significantly due to respirator usage differences?

Research Question 3 – Gender Differences

Will the cognitive function of healthy, active college males and females differ significantly from one another due to activity level or respirator usage differences?

Research Question 4 – Interactive Effects

Will the cognitive function of healthy, active college students vary significantly due to the interaction of treatment (activity intensity, respirator usage) and gender?

Research Question 5 – Individual Subject Response Variance

Will there be significant variance in cognitive function measurements due to individual subject response differences?

Discussion

The ensuing discussion is guided by the research questions and synthesizes the statistical results, inferences, and observations from this study. Both theoretical and practical contexts of the findings are discussed. Conclusions based on statistical importance ($p < .05$) are augmented by effect size, or strength of the statistical relationship, as indicated by omega squared. Observations and trends outside the realm of statistical reliability are also noted.

With a larger sample size, it is likely that additional statistical importance would have emerged. Thus, it is interesting to note differences that occurred but that were not statistically meaningful, even though the probability that these results are due to chance and not to treatment prevents drawing inferences there from. While conclusions cannot be based on differences that are not statistically reliable, their careful consideration supplements the study and may spurn further investigation. It is also interesting to note treatment and gender trends that enrich the statistical results. See Appendix F, Tables F1 for scores and F2 for times, for an integrated representation of the statistical and descriptive results that will augment this discussion.

Activity-related Effects

Research question one asks whether comparisons of cognitive function measured at rest and after acute maximal exertion would be significantly different. This research confirmed the logical assertion that thinking clarity and speed are better at rest than after maximal exertion, either with or without a respirator, for select response variables. Statistically reliable differences between the resting R and the other treatments (N, P, and S) emerged in 16.7% (2 of 12) of the score categories and 33.3% (4 of 12) of the time categories.

For MMSE score variables, statistical importance ($p < .05$) with medium effect size is evident for activity level differences for S0 total ($\omega^2 = 0.07$) and S1 orientation to time ($\omega^2 = 0.11$), both of which showed importance for activity level differences without respirator wear, between non-respirator treatments R (seated at rest) and N (post-WAnT). No important differences emerged between R and the post-WAnT respirator treatments P and S. The conclusion that mental clarity as was best at rest when no respirator was worn for S0 total scores and S1 orientation to time, is logical, considering that intense physical exertion and respirator wear, both individually and in combination, increase oxygen consumption (Zimmerman et al., 1991) and that intense physical activity causes transient decreases in cognition (Tomporowski, 2003).

For normal individuals, the questions for S1 orientation to time are elementary, so it is interesting that the results showed significance. One reason could be that it was assessed first, immediately after cessation of the WAnT, when the subject was most exhausted and while cognitive function would have been most impaired. It is of note, too, that S0 total score, which is the sum of the sectional scores, was statistically important even though for 72.7% (8 of 11) of the sectional score response variables there was no difference; and for 90.9% (10 of 11) there was no statistically reliable difference.

For MMSE time variables, statistical importance with large effect size regarding activity was evident for T0 total time ($\omega^2 = 0.28$) and two sectional times—T2 ($\omega^2 = 0.18$) orientation to place and T11 drawing ($\omega^2 = 0.14$). Resting no respirator R times were less than post-WAnT no respirator N times (T0, T2, T11) and for the air-purifying respirator P times (T0), leading to the conclusion that response time as indicated by MMSE times was best at rest when no respirator was worn for these select variables. This, too, is logical, considering the dual stressors of intense physical exertion and respirator wear, and the increased oxygen consumption (Zimmerman et al., 1991) and transient decreases in cognition (Tomporowski, 2003).

In all cases for which activity levels showed statistical importance, resting times were less than post-WAnT times, indicating significantly better cognitive performance at rest with respect to both mental clarity and response time. This finding aligns with Kayser (2003) who asserted that during exhaustive activity mental malfunction could occur because the energy demands of the brain exceed supply. Where treatment significance was identified, S mean times were lower than for all other treatments, regardless of activity or respirator usage conditions. This is surprising, considering the combined stressors of maximal activity and respirator wear of any kind (Zechman, 1957; Johnson, Dooly, & Dotson, 1995). Because the air-supplying respirator treatment yielded the fastest response times, it does not appear to adversely affect reaction time. However, carryover effect must be considered because performance on this post-WAnT respirator treatment was better than for both resting and the post-WAnT no-respirator treatment.

A look beyond statistics to mean differences adds interesting side notes. For S0 and S1, R scores exceeded all other treatments, both overall and for each gender, a trend that was also seen in the majority of score variables for which analysis was conducted. Although statistical reliability was not attained for S4 and S5, their overall mean R scores were higher than or equal to other treatments. Of the mean treatment times, the active no respirator treatment N and the air-purifying respirator treatment P had the longest times 75% and 25% of the time, respectively. With regard N, it is surprising that a no respirator treatment yielded the slowest response times (negative effect). The fastest response times occurred in R (33%) and S (67%). The active air-supplying respirator treatment S produced the lowest mean times for T0 total and 63.6% (7 of 11) of sectional times. From these results, it is apparent that the positive pressure air-supplying respirator did not adversely affect response time in this study.

Non-random treatment order and resultant carryover effect are possible reasons for the surprising results regarding the S treatment. The S trials occurred last in this study, so each subject had taken the MMSE three previous times and had performed two previous WAnT trials. In each case, subjects knew what to expect and may have been physiologically and cognitively more prepared and/or relaxed. Considering that the S trials occurred three months after N and P and two months after R, a significant carryover effect would not be expected but cannot be discounted, especially in consideration of the results. Due to the sequential progression of this research, randomized treatment order, which would have diminished the possible carryover effect of repeated measures, was not possible.

Respirator Usage Effects

Research question two asked whether comparisons of cognitive function measured after acute maximal exertion with no respirator or two types of respirator would be significantly different. Due to the discomfort of respirator wear, it is logical to predict that clarity and speed of thought would be better without a respirator because breathing, vision, and the face are unencumbered (Jones, 1991). It is also logical to predict that clarity and speed of thought would be better using an air-supplying respirator than an air-purifying respirator because of the cooling effect of air in the mask and the positive pressure inside the mask, which eases the work of breathing (Schumacher, Gray, Weidelt, Brinker, Prior, & Stratling, 2009).

Post-WAnT respirator usage differences (N, P, and S) were not statistically important for scores. For times, statistically reliable differences emerged for T0 total ($\omega^2 = 0.28$), T2 orientation to place ($\omega^2 = 0.18$), T3 registration ($\omega^2 = 0.09$), and T11 drawing ($\omega^2 = 0.14$), with one or more treatment comparisons showing statistically reliable differences with medium (T3) to large effect. For these treatment comparisons, post-WAnT no-respirator treatment N times exceeded the air-supplying respirator treatment S, and for T0 and T2, N times also exceeded the air-purifying respirator treatment P. That post-WAnT respirator treatments P and S times were faster than for no respirator treatment N was unexpected, considering the added physiological and psychological stress imposed by any respirator. Again, because S times were the fastest, with a respirator treatment yielding faster response than either no-respirator treatment, carryover effect is possible.

Looking at mean differences once more supplements the statistical results. Mean R scores were the highest, both overall and for each gender, for all analyzed score variables with one exception. In general, as would be expected, subjects scored higher in the non-stressful resting treatment. For each of the four time variables in which treatment showed significance, the treatment order for 58.3% (7 of12) of time variables from slowest (negative effect) to fastest time was NPRS. The air-supplying respirator S again yielded the most positive effects with the shortest times, followed by the resting no respirator treatment R. The active no respirator treatment N yielded the most negative effect. The fact that the air-supplying respirator provides cool air blowing in the mask and positive face mask pressure may be a factor in reducing physiological and psychological stress, thus reducing response times. However, the fact remains that wearing any respirator is stressful, and there are instances where even positive pressure inside the mask can be overcome by extreme activity requirements. Here, too, carryover effect must be considered.

That air-supplying respirator S effects were more positive than air-purifying respirator P effects is not surprising because negative respirator facepiece pressure is a factor in increased work of breathing due to the added effort for respiration (Jones, 1991). Positive pressure inside the facepiece, as with the S treatment, lessens the required work of breathing. Anecdotally, most subjects noted that the WAnT seemed easier with the air-supplying respirator (S) than with the air-purifying respirator (P). That S times were less than N and R, though, is surprising, considering that neither included respirator wear, a known physiological and psychological stressor.

That P times were also less than N is a conundrum. It is harder to breath through a respirator, especially one with negative facepiece pressure, and more so during hard physical work, which initiates an increased breathing rate and physiological demand for oxygen. A negative respirator effect with P times greater than N would be expected. Further, unlike comparisons of other treatments, N and P were performed in random order, lessening the possibility of carryover effect in their comparison. In comparing all treatments, though, the possibility of carryover effect emerges once again when considering that R and S were chronologically the last treatments.

Gender Differences

Research question three asked whether measures of cognitive function would be significantly different between males and females. Gender differences were not statistically reliable for scores, indicating no important differences in MMSE scores, and therefore thought clarity, between genders. Gender differences proved highly significant with large effect for T0 total time ($\omega^2 = 0.21$), and T4 attention and calculation time ($\omega^2 = 0.35$) times, with males emerging as the faster gender (positive effect).

Mean score differences were inconsistent. Males had higher mean scores for S0 total score, S1 orientation to time and S4 attention and calculation. For S5 recall, female scores were higher than (P, R, overall) or equal to (N, S) males. Both total and sectional female scores were, for the most part, less than males except for recall. Males were faster overall in 63.6% (7 of 11) of MMSE time sections. Females responded more quickly in T5 recall and T9 reading, and the genders were equal in T3 registration and T6 naming.

Treatment and Gender Interaction

Research question four asked whether the combination of the main effects, treatment and gender, had any interactive effects that could have either enhanced or impeded the individual results of each. The treatment-gender interaction did not show statistical reliability for total or sectional MMSE scores or times. Absence of significant interactive effects indicates that any effects of treatment and gender on the response variables are additive and that their dual occurrence does not influence the individual effect of each on the response variables. It has been argued that if a significant interactive effect is identified, the main effects should be ignored (Howell, 2002). In this study, the absence of significant interaction between the main effects allows interpretation of treatment and gender effects at face value.

Individual Subject Response Variance

Research question five asked whether there would be significant variance in cognitive function measurements due to individual subject response differences. Subject is a random factor and is not considered a predictor variable. A statistically reliable medium (T4) to large random subject effect is evident in T0 ($\omega^2 = 0.17$), T4 ($\omega^2 = 0.13$), T10 ($\omega^2 = 0.20$), and T11 ($\omega^2 = 0.16$), which indicates that for those time variables, the variance in the response of individual subjects was significant. Within any sample, even a purposeful, fairly homogeneous sample as in this study, every subject will respond uniquely, and the trend and magnitude of change might be similar or divergent, with a large variance. Important subject effects for a response variable indicate significant variance in individual subject responses for that variable, in contrast to the mean differences in the responses of all subjects that are of interest with fixed factors. That it showed importance in this sample shows that even with the attempt to homogenize sample variation with a purposeful sample, significant variance can still occur. More variance would be expected in a random sample.

Recovery Time Observations

After performance of the WAnT, subjects were not allowed to leave the research lab until all data collection was completed and their heart rate had decreased to 100 beats per minute or less, an indication that their body had recovered from the exertion. This recovery time varied widely, with some subjects reaching the required heart rate in a few minutes and others taking more than 30 minutes and needing to lie down for their heart rate to decrease to an acceptable level. This observation was surprising and anecdotal, but startling enough to report and recommend further investigation.

While all subjects were young, active and healthy, the physical activities in which they engaged differed. Some were football, basketball and volleyball players. Others were active students that exercised regularly. Data regarding their workout mode and schedule was not collected, but such information would have been an interesting addendum to this study to relate to recovery from arduous exercise. It would also be valuable information regarding the effects of the predictor variables and is suggested for future research. Practically speaking, recovery time is important with regard to worker recovery in occupational settings. Ability to perform hard work and the time for the worker to return to a normal state are both related to worker health and fitness.

Reflections on the MMSE

The MMSE was selected for this study because of the spectrum of cognitive function assessed in its sections, along with the potential for brevity of administration and for timing response with simple adaptation. Even though its original intent was for clinical assessment of dementia, its diversity and brevity make it a convenient cognitive assessment in normal individuals. With adaptation and validation by cognitive psychologists and researchers, this instrument or a similar one would be a valuable research tool to standardize cognitive function assessment. The experience of hundreds of administrations of the MMSE to normal individuals incites these recommendations (some of which were followed in this research) as suggestions to strengthen its effectiveness and expand its use for normal individuals, particularly if used for repeated measures. If timing is conducted, care should be taken for items that are changed for each test that the oral administration has the same number of syllables, thus takes the same amount of time.

1. Reduce the number of orientation to time and place items to two or three that are common knowledge and either randomize or use different ones each time. (MMSE items 1 and 2).
2. Use five different unrelated registration words for each assessment (MMSE items 3 and 5).
3. Start the serial 7 subtraction with a different starting number for each assessment (MMSE item 4).
4. Use different familiar naming items for each assessment (MMSE item 6) or eliminate this item.
5. Use a different repetition phrase for each assessment (MMSE item 7) or eliminate this item.
6. Use a multifaceted reading task that requires sequential performance three tasks, changing tasks for repeat tests.
7. Specify requiring a three to four word sentence with a subject and a verb (MMSE item 10).

8. Randomize the order of the 11 sections to minimize the effects of recovery during test administration. Subjects are most exhausted at the beginning, affecting their thought clarity and response time.

Perhaps for normal persons, more complex questions and tasks would be appropriate in order to assess cognitive differences. Adaptations to the MMSE should be made, of course, with permission. A similar assessment could be devised in consultation with a professional cognitive psychologist and cognitive researchers. Because cognition can be variously altered by a variety of factors but the evidence cannot be collated into solid substantiation of explicit effect, magnitude, or direction over the range of variables and types of cognitive assessments (Etnier et al., 2006), a standardized assessment that effectively and quickly tests a variety of cognitive areas would be a valuable research asset.

For the response variables, time difference discernment almost guaranteed treatment differences because measurement was in seconds—a sufficiently sensitive time unit for detecting differences. The score units, however, were not as sensitive. The majority of MMSE sectional scores showed no difference across treatments and genders. A more nuanced scoring system may reveal effects that were impossible to differentiate using the simplistic scoring of the MMSE. More complex questions and/or tasks may also afford more indicative scoring differences in normal individuals.

Conclusions

This research showed that cognitive function as indicated by thought clarity and speed measured by scores and times from the MMSE is significantly but selectively altered by activity, respirator usage, gender, and individual subject response variation. The answers as to how cognitive function was affected by the predictor variables are complex due to the large number of response variables and the complexity of human cognitive function and the human body. The effects of the predictor variables on the response variables are varied, sometimes incongruent, and often surprising. Specifically, the following conclusions are inferred from the statistical results of this study.

1. *Clarity of thought as indicated by higher (positive effect) select MMSE scores is better at rest with no respirator than after intense physical activity with no respirator*.

   Activity level differences, which compared R to N, P, and S, are statistically reliable for 16.7% (2 of 12) of the score variables and 33% (4 of 12) of the time variables. For scores, significant differences occurred in S0 total and S1 orientation to time for the two no-respirator treatments, R and N. For times, significant differences occurred in T0 total, T2 orientation to place, and T11 drawing for the two no-respirator treatments, R and N and, for T0, for R and P. In all comparisons, R scores were higher (positive effect) than the other treatments.

2. *Response time, as indicated by select MMSE times, is fastest (positive effect) after intense physical activity when wearing an air-supplying respirator.*

   Post WAnT respirator usage differences are statistically significant for 25% (4 of 12) of the time variables—T0 total time, T2 orientation to place, T3 registration, and T11 drawing—but no score variables. Significant differences occurred in all four time variables between S and N and, for also between S and P for T0 and T2. In all comparisons, S times were lower (positive effect) than the other treatments.

3. *Response time, as indicated by select MMSE times, is fastest (positive effect) for males*. Gender differences are statistically significant for 16.7% (2 of 12) of the time variables—T0 total time and T4—and no score variables. For these time variables, male times were lower (positive effect) than females.

4. *Significant variance in individual subject response measurements occurred in select time variables*. Individual subject response variation proved statistically significant for 33.3% (4 of 12) of the time variables—T0 total time, T4 attention and calculation, T10 writing, and T11 drawing, and no score variables. This indicates a wide dispersion in intra-subject responses, which in turn may affect mean differences. For T0 and T4, which also showed gender importance, the gender differences may have contributed to the significant subject variance differences.

As indicated in the above summary, statistical significance occurred in select MMSE scores and times. Overall, changes seen in the majority of both score and time response variables were likely due to chance and not to treatment, gender, main effects interaction, or random subject variance. Significant multiple predictor effects were seen T0 total time, affected by treatment, gender, and subject; T4 attention and calculation time, affected by gender and subject; and T11 drawing time, affected by treatment and subject. The only MMSE category that showed statistically reliable effect for both scores and times was total score and time (S0 and T0) for treatment comparison R-N, at rest with no respirator R compared to post-WAnT with no respirator N. In both cases, the positive effect was for R, with R scores exceeding N scores and R times less than N times.

Treatment and Gender Trends and Considerations

The majority of the response variables did not yield statistically reliable differences due to treatment and gender. However, there are trends and observations from this study whose significance did not attain the requisite probability but that may be important indicators of effect and deserve consideration and further exploration. Refer to Appendix F, Tables F1 and F2, to see these trends.

Although gender did not yield statistically reliable score differences, males outscored females in total (1.0%), orientation to time (3.0%), and attention and calculation scores (5.5%), but not in recall (7.1%) scores. Scores did not differ for the other score response variables. Gender yielded statistical reliability time differences only for total time and attention and calculation time, but male times were less than female for all time parameters (mean difference 14.4%) except recall (mean difference 3.9%) and reading (15% difference). Male and female times were equal in registration and naming.

The gender trends regarding cognitive function, while possibly due to chance, are evident in these results and warrant further study. In the resting no-respirator treatment R, females outscored or equaled males in all but S4 attention and calculation; but for the post-WAnT treatments (N, P, and S), females only outscored males for the air-purifying treatment P in S5 recall. Time results were similar, with male times less than female for 41.7% (8 of 12) of the response variables and, overall, for all treatments. Females fared best in the air-supplying respirator treatment S, for which their times were less than males for 41.7% (5 of 12) of the response variables.

The WAnT workload resistance was relative to the individual’s body weight. Males are generally stronger and have more relative muscle mass (ratio of muscle mass to total mass) than females, which could be a factor in the gender-related differences that favor males. Because body fat percentage and leg strength were not determined for the subjects, this assumption cannot be tested. In contrast to the better male reaction time in this study, Caretti (1997) found female reaction time to be faster than males at rest, suggesting that gender differences in reaction time may be specific to the activity level, with males performing better during hard work and females reacting more quickly at rest. Further study will clarify these questions.

In this study, positive effect was assumed with higher MMSE scores, representing better thought clarity, and lower MMSE times, representing faster reaction time. Mean differences for statistically reliable ($p < .05$) treatment score differences from highest (R) to lowest (N) S0 total score were 3.9% and for S1orientation to time, 8.7%. Mean differences for statistically reliable ($p < .05$) treatment time differences from lowest (S) to highest (N) times were 22.2% (T0), 24.5% (T2), 39.0% (T3), and 57.7% (T11). Mean differences showed that, for select variables, the clearest thinking occurred with no activity or respirator (R), and the fastest response time occurred post-WAnT wearing an air-supplying respirator (S). Because post-WAnT respirator wear yielded more positive results than the resting or post-WAnT no respirator treatments, the possibility of carryover effect cannot be dismissed, since both intense activity and respirator wear stressors.

Conclusions cannot be drawn from non-reliable statistical results ($p > .05$). However, the following trends are noted as possible indicators of effect, and thus considerations for future study.

1. The highest mean treatment scores (positive effect) occurred in the resting no-respirator treatment R. Mean R scores equaled (S5) or exceeded all other mean treatment scores except the air-purifying respirator S (3.6% difference). N scores were the lowest (negative effect) except for S5 recall, in which R and N were equal. This trend seems logical considering the absence of the activity and respirator stressors in the R treatment but also surprising because for post-WAnT treatments, the two respirator treatments (P, S) yielded more positive results than the no respirator treatment (N).
2. The fastest mean treatment response times (positive effect) occurred in the post-WAnT air-supplying respirator treatment S in 75% (9 of 12) of the time

response variables, with the resting no respirator treatment R lowest for the other three variables (T6, T8, and T9).

3. The slowest mean treatment response time (negative effect) occurred in the post-WAnT no-respirator treatment N in 75% (9 of 12) of the time response variables, with the post-WAnT air-purifying respirator P slowest for the others. These treatments were chronologically the first two, though their administration order was random, and one would expect N to be the less stressful of the post-WAnT treatments, which was not the case. These trends suggest carryover effect, with the first two treatments, N and P, yielding the most negative results, and the last treatment, S, yielding the most positive results, despite the fact that it includes both activity and respirator stressors.
4. The scores treatment order from highest (positive effect) to lowest score was RSPN for S0 total score and S4 attention and calculation, RPSN for S1 orientation to time, and RNSP for S5 recall. Second place is shared by the other treatments, with N and P occupying last place for all score variables. It is not surprising that the resting no-respirator score is highest, a logical positive effect trend for the resting no respirator treatment considering the absence of the activity and respirator stressors.
5. The times treatment order from slowest response (negative effect) to fastest response was NPRS for 71.2% (7 of 12) of the time response variables. This is the approximate chronological treatment order except for N and P, which were randomly assigned. The remaining treatment orders were NPSR for two response variables (T9, T10), PRNS (T5), PNSR (T6), and PNRS (T8). Note that in all cases, S and R were the lowest time/fastest response (positive effect).

> That P times were higher than S and R is logical in that the work of breathing for an air-purifying respirator is greater than for an air-supplying respirator or no respirator. That N times were higher the majority of the time and that the positive effect trend follows the treatment order makes a case for carryover effect.

A deeper look at these data regarding trends not evident from statistical testing raises thought-provoking possibilities for future studies and for insuring adequate sample size, random order, and elimination of all other possible threats to validity. All changes or trends warrant consideration and further investigation to ascertain whether they are reliable or due to chance, particularly when considering the complexity and subtleties of the human body, with its delayed reactions, buffering systems, and compensatory and adaptive mechanisms. The assorted and often contradictory results of this and other research suggest that the mechanisms for cognitive adaptation to respirator wear during work are not always apparent and/or are diverse and complex. What may seem incidental or irrelevant could be the tip of the iceberg.

Human Factors

The human body and mind are dynamic entities in constant flux, and individual and situational factors can quickly change and possibly disrupt the equilibrium that each organism strives to maintain. Such disruptions may be triggered by small, seemingly insignificant changes and may occur at different times and intensities for the same or different people, depending upon their individual characteristics and their particular physical and mental state at a given time. Human adaptation to stress occurs from system to system in a reciprocal balancing act that may or may not be quantifiable or outwardly evident, at least at the onset. Therefore, an expected or necessary response may not occur because the stimulus is buffered, or equalized, or overcome by another system.

The inferences and observations from this study are important concerning the health and safety of workers that perform hard work, wear respirators, or both. For their sake, scrutiny of federal and employer regulation of respirator wear with regard to worker health and fitness, work intensity, and respirator wear and selection is advised. Even though the treatment combinations of activity (maximal cycling or seated at rest) and respirator usage (respirator wear or not) do not mimic any normal work activity, still the physiological and cognitive results have application in a broader sense. While these data are from a limited sample of a restricted population and collected in a safe, controlled environment, careful consideration of the effects is prudent when considering human safety and health, particularly when effects noted in active, healthy young subjects could be more profound in a more vulnerable (anxious, older, less healthy) population working in a hazardous environment.

In summary, analysis of the MMSE scores and times yielded selective statistically reliable differences related to treatment, gender, and individual subject response. These effects were sporadic across the predictor and response variables and results indicate that activity intensity affects both total and some sectional scores and times. Respirator usage was found to affect cognitive function, but it is interesting to note that the greatest positive effect for MMSE times occurred for a post-exertion respirator treatment, not, as one might expect, at rest with no respirator. Score differences varied between genders, though for significant variables, male scores were higher. Male times were faster than female times for the most part. Individual subject response was an important factor for total and three sectional times. Due to the sample and carryover limitations of this study, further research is needed to confirm the results. While these results cannot be generalized beyond the population of active, healthy young college students, one can theorize that they would be more profound in a more vulnerable population such as the workforce.

Implications

These results inform the research, occupational, and regulatory worlds that in this study, cognitive function was affected by differences in activity levels, respirator usage, gender, and individual subject response variations; and that air-supplying respirators appeared to be better than air-purifying respirators with regard to cognitive function. Changes in cognitive function due to respirator wear and activity level are not generally considered an occupational hazard, yet the effects thereof could be critical. Heightened awareness of the possibility, potential danger, and possible causes of cognitive deficit should be considered and accounted for in safety and health programs and policies, worker education and occupational regulations.

Worker physical fitness and workload intensity requirement should be considered when assigning work. These findings show that where statistically reliable differences in cognitive clarity (MMSE scores) occurred, it was better at rest than after maximal activity with no respirator wear for overall score and orientation to time. While changes in most sectional score variables were non-existent or not significant, total score as an index of overall cognitive function did show importance. If cognitive function, when measured in optimal conditions, is detrimentally affected by maximal activity in the population of active, healthy young college students, it is likely that similar or more profound effects could occur in workers performing hard work in actual work conditions.

A respirator that provides positive pressure inside the mask lessens the work of breathing and should be offered as a respirator choice and perhaps required for *vulnerable workers.* The positive effect of the air-supplying respirator regarding response time, both overall and for each gender, for total time, orientation to place, registration, and drawing is another statistically important result of this study. While carryover effect must be considered, from these findings it is apparent that the air-supplying respirator is less cognitively stressful and a respirator choice that should be offered to respirator wearers when the job permits. An option that would be similar yet would not limit mobility due to the airline would be a powered air-purifying respirator, which blows air into the respirator mask. Research on the cognitive effects of this type of respirator is needed.

Male response time was faster than female. The statistically important gender differences seen for total time and attention and calculation are important regarding physical capacity and workload determination. Males responded more quickly than females, which could have been due to the intensity of the work. As previously stated, whenever rigorous work could be required, the worker's physical fitness and functional capacity should be measured to insure that they are physically able to do the work and adequately recover.

Individual subject response variability was an important factor regarding response time differences. Because every human is different, some variation in response is normal and expected. In spite of the intentional similarity of subject characteristics in this study with regard to activity, education, and age, significant variation in response was found for select time variables. This aligns with similar findings in a study of respirator use and productivity in mentally challenging work at rest, in which subject variability consistently affected performance speed and accuracy (Jaraiedi, Iskander, Myers, & Martin, 1994). Although it is not possible to control completely for worker individuality, assuring that workers have a minimum level of physical fitness will minimize significant variance in this important characteristic, thus increasing confidence that the worker is capable of safely performing the required task with or without a respirator.

Consider the following scenario. A 55-year old sedentary but asymptomatic worker was approved for respirator wear by completing a respirator fit test and the medical clearance questionnaire, on which several items confused him. He did not see a health care professional to clarify his questions. His job periodically requires performance of hard work in a potentially hazardous atmosphere while wearing an air-purifying respirator. Whenever this is required, he feels physiologically stressed by the workload and work of breathing and psychologically stressed due to the hazardous atmosphere and respirator discomfort. During one such work session, he felt disoriented and exhausted. When a machine malfunction occurred requiring him to respond quickly and succinctly, he hit the wrong button, and caused a fatal accident.

This scenario is entirely possible. How could it have been prevented? Face-to-face interaction by a health care professional and assessment of the worker's health and fitness would have evaluated his ability to perform hard work. Wearing a positive pressure respirator may have lessened the work of breathing and decreased his physiological and psychological stress and prevented the accident. Educating him about his own health and fitness, signs and symptoms of overload and to get help if he is in distress may have made a difference.

Protection from breathing a hazardous atmosphere is a worthy tradeoff for the discomfort and stress inherent to respirator wear, but for vulnerable respirator wearers, the added stress may initiate discrete or integrated responses that could lead to a "critical effect threshold" (Bardsley, Amtmann, & Spath, 2005) such as cardiorespiratory or muscular overload (exhaustion), heart attack, anxiety, or disorientation. Such effects cross the line from being a nuisance to being or initiating a crisis. Effect thresholds likely differ both among workers as a function of individual physiological and psychological characteristics and even within the same person, depending on acute situational or individual factors such as heat, work task intensity, illness, or mental stress.

Those with greater capacity for work and adaptation generally have more reserves for adjusting to both physiological and psychological changes and challenges. For such workers, the added stress of intense exertion and respirator wear may be easily assimilated. Others with limited or no reserves or capacity for adaptation may be pushed beyond safe limits to a physiological and psychological danger zone. There is no way to predict the threshold at which a critical incident could occur. Warning signs may not exist, be undetectable or ignored, or occur too suddenly or too late to make a difference. One person’s thresholds may shift from day to day. On the one hand we have a critical effect threshold and at the other end of the spectrum, peak performance (Palmer, 2007). Most human beings have experienced both extremes in some area of existence, whether physiological, emotional, or cognitive.

Palmer (2007) describes the Peak Performance Model that proposes the Optimal Performance Zone (OPZ)—a dynamic concurrence of physical, psychological and environmental factors in ideal balance and within which optimal performance is attained. Recall the possibility of an optimal interaction between exercise level and cognitive function posed by Kashihara et al. (2009). If there is in fact an activity level at which the select cognitive ability is best performed and above and below which performance is diminished, is there, too, a Critical Effect Threshold (CET)—also a dynamic juxtaposition of said factors, but in this case the point at which performance begins to critically break down and adaptive and compensatory mechanisms overload or fail?

Everyone has both an OPZ—a physical, psychological balance that is as good as it gets—and a CET—the last straw, the point where we “lose it” whether physically, psychologically, or both. Consider that heart attack is consistently the major cause, around 40 percent, of on-duty firefighter deaths in America each year (Fahy, LeBlanc & Molis, 2008). Each of those firefighters went to work not expecting to die from the rigors of their job. Everyone’s limits are individual, variable, and largely unpredictable. And their capabilities and insidious disease factors are not always obvious.

The physiological and cognitive OPZ of a finely tuned elite athlete may be wide and deep. Conversely, the physiological and cognitive OPZ of a sedentary middle-aged worker may be tenuous and shallow. Add a respirator and require intense physical labor and the CET may be crossed and clear, quick thinking and response may be impossible, as illustrated in the scenario just discussed. How integrated are the physiological and psychological CETs and what are the mechanisms by which they are connected? Would the rigors of the WAnT or other intense physical activity, respirator or not, cross the physiological and/or cognitive CET?

One way to address these questions and issues is to evaluate cognitive response in a stressful situation—hence this study and the use of the MMSE to assess cognitive differences from arduous activity and respirator usage in active, healthy young adults. Proactive identification of the effects of workplace stressors provides important information relevant to worker safety and health. The physiological and cognitive critical effects within an individual may cause a critical incident that not only affects that person but also others, the workplace, and the environment.

This information is important to employers that require employees to wear respirators and to safety and health professionals that must select proper respiratory protection. It is important to regulatory agencies such as OSHA whose mission is to ensure worker health and safety and to promulgate and enforce standards that support that mission. It is important to researchers and research agencies such as NIOSH whose studies on respiratory protection and other workplace factors contribute to improvement in worker health and safety. Finally, it is important to anyone that may be required to perform hard work wearing a respirator in a potentially hazardous atmosphere.

Everyone involved in occupational respirator wear or selection should know the respirator's protection and limitations and the physiological and psychological effects of respiratory protection, as well as the stamina required for task performance and the capacity of each worker to safely and competently perform said task, with or without a respirator. Determination of worker ability to tolerate the additional strain of a respirator should include assessment of physical fitness, health, work characteristics, and respirator type and specifications (Szeinuk, Beckett, Clark, & Hailoo, 2000).

For employers and occupational safety and health professionals, thorough screening of the worker and job task is a key factor. Both new and incumbent workers should be assessed for respirator wear and job fitness on a regular basis (Sharkey & Davis, 2008). Consider the aged and aging workforce. The "older worker" is defined as anyone 40 years or older by the Age Discrimination and Employment act. Before long, these workers will constitute the largest segment of America's workers (Kowalski, Steiner, & Schwerha, 2005). Medical approval assessing worker health and fitness, work requirements, and respirator properties, essential for persons that must wear respirators (Szeinuk, Beckett, Clark, & Hailoo, 2000), is even more critical for the aging workforce.

Another key factor is worker education about the job rigor, respirator wear effects and limitations, and the worker's own limitations. More than just training an employee on rote performance of a task, or having them complete a questionnaire without guidance or supplemental information, education involves providing them with knowledge, understanding and awareness of their and the respirator's capabilities and limitations, and the dynamic nature of their overlap. Such education should include awareness of the cognitive effects of occupational stressors. This is often overlooked because cognitive change and impairment are not casually obvious or measurable and can be subtle in onset yet devastating in consequence.

A final key factor is diligent attention to the interface between the worker, protective equipment, job task, environment, and situation. This responsibility is shared by management, safety and health professionals, and employees, as all must be stakeholders in the inherent importance of safety and health for every worker and workplace consideration. Safety hazards, air concentrations, respirator fit, and most other occupational factors can readily be examined and measured. However, covert human factors such as worker fitness and cognitive function are easy to overlook. Yet they are crucial factors in the quest to establish and maintain a truly safe and healthy workplace and work force and a comprehensive safety and health program.

This study showed that cognitive function is selectively affected by activity intensity, that response time is best with air-supplying respirators, and that after intense work, males respond more quickly than females. This information will be clarified by further investigation. The implications and application of these findings are important in the fields of occupational safety and health, exercise and work physiology, and occupational health psychology. When these results are published, they will hopefully spurn further inquiry, more in-depth regulation, and careful worker screening and education about the effects of and interplay among cognitive function, respirator wear, intense activity, and gender differences.

Recommendations

Where does the information gleaned from this study fit? The implications of this study not only provide impetus for continuation of this line of research and refinement and expansion of this study, but also for reconsideration and updating of current policies and procedures about health, hard work, and respirator wear. Suggestions for future research outline possible pathways for more in-depth description of the complex interaction of cognitive function, activity, and respirator wear. The following recommendations address regulatory, practical, and theoretical suggestions.

Regulatory Recommendations

The primary federal agencies for occupational safety and health regulation and research, OSHA and NIOSH, have made enormous differences in addressing workplace hazards. The negative reputation that OSHA often gets as the “safety police” ignores the tremendous strides in workplace safety and the multitudes of lives that have been saved due to OSHA regulations. The research and health hazard evaluations conducted by NIOSH not only inform OSHA but also workers and the public. Together these agencies provide tremendous information, protection and service to working Americans. Recommendations to NIOSH, the federal occupational safety and health research agency, are included below in recommendations to researchers. The following recommendations to OSHA would strengthen regulation of worker safety and health and thus worker protection.

1. Review the Respiratory Protection Standard and strongly consider requiring face-to-face medical evaluation of workers that may be required to wear

respiratory protection. The current practice of completion of a self-administered questionnaire and cursory, often remote review by a health care professional is inadequate to insure that the worker understands the questions, tells the truth, and is physically and psychologically healthy enough to wear a respirator. In the face-to-face evaluation, assess the person's ability to think clearly and quickly while performing the expected workload wearing a respirator.

2. Recommend or require provision of air-supplying or powered air-purifying respirators that provide constant positive pressure inside the respirator facepiece as an option or requirement for individuals with health or respirator-wear issues or for workers expected to perform arduous work.

Employer Recommendations

The following recommendations to employers go beyond just compliance with OSHA standards to prudent action for maximal protection of their workers. These recommendations protect both employee health and employer liability.

1. Hire or contract an educated occupational safety and health professional to address worker health and safety concerns and, specific to this research, to evaluate worker ability to think clearly and quickly while wearing a respirator during performance of hard physical labor.
2. Require workers that will wear respirators to have a face-to-face medical evaluation in which they are evaluated by a health care professional for health, physical fitness, and ability to think clearly and respond quickly while wearing a respirator. The health care professional should review and clarify the questions on the medical questionnaire in person.

3. Educate workers regarding the rigors of their job and the physiological and psychological effects and limitations of respirator wear, and insure that they are physically fit enough to perform the tasks without undue stress. Workers need to know what is expected of them and whether they are capable of performing the job.
4. Provide air-supplying or powered air-purifying respirators that deliver constant positive pressure airflow inside the respirator facepiece as an option or requirement for individuals with health or respirator-wear issues or for workers expected to perform arduous work.

Research Recommendations

The following general recommendations provide ideas for research in general. They are followed by research recommendations for continuation of this and related pathways of research.

1. Insure equal gender representation in studies whenever possible. Gender differences have been noted in several studies, though often researchers do not insure gender equality in their studies. The gender-related differences in effects evident in this study indicate possible inter-gender mechanisms for adaptation and compensation to physiological or psychological stressors that should be identified. Future research in all areas should include male and female subjects, both to eliminate gender bias and to define important gender-specific responses and effects. It has been suggested that researchers also document where a woman is in her cycle, though Gordon and Lee (1993) found no difference in cognition due to phase of menstrual cycle.

2. Measure recovery time after exertion in physiological research. As previously discussed, recovery times varied significantly within the sample. In any research involving physical exertion, recording recovery time to a given heart rate would provide an index of how long it takes the cardiorespiratory system to recover from the exertion. The WAnT was a 30-second sprint. That some subjects took over 30 minutes to attain a recovery heart rate of 100 beats per minute was surprising and thought-provoking. The relevance and implications of this knowledge span various fields of study. Occupationally, consider that even after a physiologically or psychologically stressful event is over, the worker may still be far from recovery and far from the OPZ. Further, the effects of the stressor(s) could initiate a physiological chain reaction, crossing the CET and leading to a crisis whose onset is not readily apparent.

Research related to this study. Should this study be replicated in its entirety or in part, the following suggestions would strengthen and diversify the results.

1. Randomize treatment order to minimize the carryover effect of repeated measurements. As discussed, random treatment order is proper research practice and may have compromised the results of this study.

2. Randomize MMSE section order to eliminate recovery effect. Subjects are most exhausted at the beginning of the MMSE and recover progressively during the progression of the assessment.

3. Replicate this study with 30 or more subjects for optimal statistical results, and include powered air-purifying respirators as a treatment.

4. Use a random, not purposeful sample, and a submaximal exercise protocol. The rigor of a maximal exercise protocol such as the WAnT would prove too uncomfortable and perhaps too risky for a random sample. Submaximal activity is more likely in the workplace, though maximal activity may be required.

5. Use a purposeful sample (and hopefully a larger sample size) but have subjects perform a submaximal protocol for a longer period of time, either to exhaustion or to another predetermined endpoint. There are various submaximal exercise protocols that could be used. Once again, submaximal activity is more likely in the workplace.
6. Conduct similar research with a different type of activity. While cycling affords easier data collection and subject safety and control, it is not similar to any normal work activity. A weight-bearing activity mode such as treadmill walking or resistance training more closely simulates work activities. Chang and Etnier (2009) contend that the cognitive effects of resistance exercise have heretofore been ignored and yield positive effects.
7. In conjunction with one of the trials or at a separate session, administer a fitness evaluation to measure each subject’s health-related fitness in the areas of aerobic (cardiorespiratory) fitness, upper and lower body strength, and body composition (percent body fat and body mass index or BMI) to relate these parameters to cognitive results.
8. Before data collection, along with the health history, informed consent, and other prefatory information, survey subjects regarding their activity level and mode—how often and long they exercise and what types of exercise do they do. After data collection, administer a brief survey to subjects about their

subjective impressions of the activity, respirators, effects on cognition, and other parameters.

9. Include rate of perceived exertion (RPE) as a data component to elicit subjects' estimation of their exertion and to compare this perception across treatments. In an unpublished study comparing respirator usage and activity, RPE differences between respirators were statistically reliable.

10. Survey the subjects regarding their perception of the cognitive and physiological effects and discomfort during and after WAnT.

Summary of Chapter Five

In Chapter Five, the research questions and results were collated to draw conclusions about activity intensity, respirator wear and gender differences, and allow a shift in perspective from just statistical considerations to contemplation of more subtle results that could be important, are worth noting, and warrant further study. Cognitive changes were identified related to gender, activity level and respirator usage differences. While this study has various limitations, it also has both practical and theoretical applications and implications important to regulatory agencies, employers, and researchers.

Due to the purposeful sample, small sample size, possible carryover effect, and disparity between laboratory and work conditions, the results of this study are necessarily limited in their application and interpretation. Nevertheless, they are provocative and perhaps important indicators for any population for which arduous work with or without respirator wear is a possibility. Because cognitive changes occurred in active, healthy young adults, in a controlled environment, generalization to the working population is not prudent. However, it would also be imprudent to discount these results because cognitive effects seen in this young, active, and healthy sample could be intensified in an older, less healthy population in real-world conditions. Consider that the graying of the workforce is undeniable, and little is known about worker adaptation to physical and cognitive declines due to aging.

Publication of this study is the next step, with the hope that these results showing cognitive changes related to gender, activity levels and respirator usage will raise awareness and initiate action and further research that refines and expands upon these and related findings. These results answer some questions, raise others, and provide a framework for continued exploration of cognitive change from different modes and intensities of activity, different types of respirators, and more. An increasing network of knowledge will grow as this line of research develops and deepens in the quest to explore and explain the unknown.

Denouement

It has been said that the whole is greater than the sum of its parts. This notion can be pondered across the gamut of disciplines and facets of life—philosophy, biology, psychology, education, research, and more. The collation of discrete parts with a common purpose creates a synergy and effect that is more than just a collection of pieces. Consider the atom, the human being, education, research, and more. In each case there are intangible mechanisms that unite the discrete parts into a cohesive whole with its own dynamics and characteristics. Sometimes, though, we must examine the parts in order to fully describe, appreciate or understand the whole, even knowing that something may be lost in dissection.

This study is an example of such an enterprise, with respect to both this research project and the research process as a whole. While the study itself departs from the norm and framework of Curriculum and Instruction dissertations, the research process itself was curriculum and instruction personified as this novice investigator in turn guided novice graduate student investigators through their research projects, from inception through publication. The research team, the subjects, the methodology, the data, and the results are each entities unto themselves that at the same time contributed to the totality of this project.

The investigation of human cognitive response to physiological stressors comprised the formal study, but teaching, learning, teamwork, mistakes, revelations, brainstorming, frustration, and so much more also occurred—the rich and deep qualitative ramifications of this quantitative exploration. In these studies to discover the magnitude of physiological and cognitive changes as parts of the complex and fascinating whole of human subjects, we also discovered a great deal about the research process and about ourselves, both individually and as cogs in the wheels of discovery and of humanity. The beat goes on as researchers fill in knowledge gaps through quantitative and qualitative investigation and in so doing grow as human beings.

Data are collected and analyzed. Results are reported and conclusions drawn. Dissertations are defended, published and cited. Grades and degrees are conferred. But the intangibles—the camaraderie, effort, knowledge, experience, insight and humility gained in the process—are perhaps the most important yet elusive aspects. They, too, are parts that constitute a greater whole. And on a deeper level they contribute to the singular and essential body of knowledge about oneself and to the progression of one's apprenticeship as a scholar and as a human being.

The processes and experiences leading to this denouement are rich, complex and in many ways defy description. This dissertation is an attempt to collate the experience into an intelligent, organized, creative document that makes sense of and gives credibility to the totality. While some things may be lost in translation and interpretation, others are gained in the blood, sweat, and tears of the attempt. Life is education, and my dissertation and the associated effort are and will always be an indelible and very significant part of the whole of my education. While it will never be perfect—there is always something that would improve it—at this point, I, the researcher-writer humbly let it go to be what it is and to make its unique contribution.

The wisdom gained from life and effort defies statistical analysis—it cannot be measured. There is no set curriculum. The instruction is never-ending and sometimes excruciating. While some learning and knowledge can be quantified, deeper knowing defies description or measurement. The effect size is incalculable but vast and unmistakable.

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Appendix A

OSHA Respirator Medical Evaluation Questionnaire

(OSHA, 1998)

• Part Number:	1910
• Part Title:	Occupational Safety and Health Standards
• Subpart:	I
• Subpart Title:	Personal Protective Equipment
• Standard Number:	1910.134 Appendix C
• Title:	OSHA Respirator Medical Evaluation Questionnaire (Mandatory).

Appendix C to Sec. 1910.134: OSHA Respirator Medical Evaluation Questionnaire

To the employer: Answers to questions in Section 1, and to question 9 in Section 2 of Part A, do not require a medical examination.

To the employee: Can you read (circle one): Yes/No

- Your employer must allow you to answer this questionnaire during normal working hours, or at a time and place that is convenient to you.
- To maintain your confidentiality, your employer or supervisor must not look at or review your answers, and
- Your employer must tell you how to deliver or send this questionnaire to the health care professional who will review it.

Part A. Section 1. (Mandatory) The following information must be provided by every employee who has been selected to use any type of respirator (please print).

1. Today's date:____

2. Your name:____

3. Your age (to nearest year):_____________________________________

4. Sex (circle one): Male/Female

5. Your height: __________ ft. __________ in.

6. Your weight: ____________ lbs.

7. Your job title:____

8. A phone number where you can be reached by the health care professional who reviews this questionnaire (include the Area Code): ____________________

9. The best time to phone you at this number: ________________

10. Has your employer told you how to contact the health care professional who will review this questionnaire (circle one): Yes/No

11. Check the type of respirator you will use (you can check more than one category):

    a. ______ N, R, or P disposable respirator (filter-mask, non-cartridge type only).

    b. ______ Other type (for example, half- or full-face piece type, powered-air purifying, supplied-air, self-contained breathing apparatus).

12. Have you worn a respirator (circle one): Yes/No

    If "yes," what type(s):____

Part A. Section 2. (Mandatory) Questions 1 through 9 below must be answered by every employee who has been selected to use any type of respirator

- please circle "yes" or "no".

1. Do you ***currently*** smoke tobacco, or have you smoked tobacco in the last month: Yes/No

2. Have you ***ever had*** any of the following conditions?
    a. Seizures (fits): Yes/No
    b. Diabetes (sugar disease): Yes/No
    c. Allergic reactions that interfere with your breathing: Yes/No
    d. Claustrophobia (fear of closed-in places): Yes/No
    e. Trouble smelling odors: Yes/No

3. Have you ***ever had*** any of the following pulmonary or lung problems?
    a. Asbestosis: Yes/No
    b. Asthma: Yes/No
    c. Chronic bronchitis: Yes/No
    d. Emphysema: Yes/No
    e. Pneumonia: Yes/No
    f. Tuberculosis: Yes/No
    g. Silicosis: Yes/No
    h. Pneumothorax (collapsed lung): Yes/No
    i. Lung cancer: Yes/No
    j. Broken ribs: Yes/No
    k. Any chest injuries or surgeries: Yes/No
    l. Any other lung problem that you've been told about: Yes/No

4. Do you ***currently*** have any of the following symptoms of pulmonary or lung illness?
    a. Shortness of breath: Yes/No
    b. Shortness of breath when walking fast on level ground or walking up a slight hill or incline: Yes/No
    c. Shortness of breath when walking with other people at an ordinary pace on level ground: Yes/No
    d. Have to stop for breath when walking at your own pace on level ground: Yes/No
    e. Shortness of breath when washing or dressing yourself: Yes/No

- f. Shortness of breath that interferes with your job: Yes/No
- g. Coughing that produces phlegm (thick sputum): Yes/No
- h. Coughing that wakes you early in the morning: Yes/No
- i. Coughing that occurs mostly when you are lying down: Yes/No
- j. Coughing up blood in the last month: Yes/No
- k. Wheezing: Yes/No
- l. Wheezing that interferes with your job: Yes/No
- m. Chest pain when you breathe deeply: Yes/No
- n. Any other symptoms that you think may be related to lung problems: Yes/No

5. Have you ***ever had*** any of the following cardiovascular or heart problems?
- a. Heart attack: Yes/No
- b. Stroke: Yes/No
- c. Angina: Yes/No
- d. Heart failure: Yes/No
- e. Swelling in your legs or feet (not caused by walking): Yes/No
- f. Heart arrhythmia (heart beating irregularly): Yes/No
- g. High blood pressure: Yes/No
- h. Any other heart problem that you've been told about: Yes/No

6. Have you ***ever had*** any of the following cardiovascular or heart symptoms?
- a. Frequent pain or tightness in your chest: Yes/No
- b. Pain or tightness in your chest during physical activity: Yes/No
- c. Pain or tightness in your chest that interferes with your job: Yes/No
- d. In the past two years, have you noticed your heart skipping or missing a beat: Yes/No
- e. Heartburn or indigestion that is not related to eating: Yes/No
- f. Any other symptoms that you think may be related to heart or circulation problems: Yes/No

7. Do you ***currently*** take medication for any of the following problems?
- a. Breathing or lung problems: Yes/No
- b. Heart trouble: Yes/No
- c. Blood pressure: Yes/No
- d. Seizures (fits): Yes/No

8. If you've used a respirator, have you ***ever had*** any of the following problems? (If you've never used a respirator, check the following space and go to question 9:)
- a. Eye irritation: Yes/No
- b. Skin allergies or rashes: Yes/No
- c. Anxiety: Yes/No
- d. General weakness or fatigue: Yes/No
- e. Any other problem that interferes with your use of a respirator: Yes/No

9. Would you like to talk to the health care professional who will review this questionnaire about your answers to this questionnaire: Yes/No

Questions 10 to 15 below must be answered by every employee who has been selected to use either a full-facepiece respirator or a self-contained breathing apparatus (SCBA). For employees who have been selected to use other types of respirators, answering these questions is voluntary.

10. Have you ***ever lost*** vision in either eye (temporarily or permanently): Yes/No

11. Do you ***currently*** have any of the following vision problems?
    a. Wear contact lenses: Yes/No
    b. Wear glasses: Yes/No
    c. Color blind: Yes/No
    d. Any other eye or vision problem: Yes/No

12. Have you ***ever had*** an injury to your ears, including a broken ear drum: Yes/No

13. Do you ***currently*** have any of the following hearing problems?
    a. Difficulty hearing: Yes/No
    b. Wear a hearing aid: Yes/No
    c. Any other hearing or ear problem: Yes/No

14. Have you ***ever had*** a back injury: Yes/No

15. Do you ***currently*** have any of the following musculoskeletal problems?
    a. Weakness in any of your arms, hands, legs, or feet: Yes/No
    b. Back pain: Yes/No
    c. Difficulty fully moving your arms and legs: Yes/No
    d. Pain or stiffness when you lean forward or backward at the waist: Yes/No
    e. Difficulty fully moving your head up or down: Yes/No
    f. Difficulty fully moving your head side to side: Yes/No
    g. Difficulty bending at your knees: Yes/No
    h. Difficulty squatting to the ground: Yes/No
    i. Climbing a flight of stairs or a ladder carrying more than 25 lbs: Yes/No
    j. Any other muscle or skeletal problem that interferes with using a respirator: Yes/No

Part B Any of the following questions, and other questions not listed, may be added to the questionnaire at the discretion of the health care professional who will review the questionnaire.

1. In your present job, are you working at high altitudes (over 5,000 feet) or in a place that has lower than normal amounts of oxygen: Yes/No
If "yes," do you have feelings of dizziness, shortness of breath, pounding in your chest, or other symptoms when you're working under these conditions: Yes/No

2. At work or at home, have you ever been exposed to hazardous solvents, hazardous airborne chemicals (e.g., gases, fumes, or dust), or have you come into skin contact with hazardous chemicals: Yes/No

If "yes," name the chemicals if you know them:_________________________
____

3. Have you ever worked with any of the materials, or under any of the conditions, listed below:

a. Asbestos: Yes/No
b. Silica (***e.g.***, in sandblasting): Yes/No
c. Tungsten/cobalt (e.g., grinding or welding this material): Yes/No
d. Beryllium: Yes/No
e. Aluminum: Yes/No
f. Coal (for example, mining): Yes/No
g. Iron: Yes/No
h. Tin: Yes/No
i. Dusty environments: Yes/No
j. Any other hazardous exposures: Yes/No

If "yes," describe these exposures:____________________________________
____

4. List any second jobs or side businesses you have:___________________
____

5. List your previous occupations:_____________________________________
____

6. List your current and previous hobbies:________________________________
____

7. Have you been in the military services? Yes/No
If "yes," were you exposed to biological or chemical agents (either in training or combat): Yes/No

8. Have you ever worked on a HAZMAT team? Yes/No

9. Other than medications for breathing and lung problems, heart trouble, blood pressure, and seizures mentioned earlier in this questionnaire, are you taking any other medications for any reason (including over-the-counter medications): Yes/No

If "yes," name the medications if you know them:_______________________

10. Will you be using any of the following items with your respirator(s)?

a. HEPA Filters: Yes/No
b. Canisters (for example, gas masks): Yes/No
c. Cartridges: Yes/No

11. How often are you expected to use the respirator(s) (circle "yes" or "no" for all answers that apply to you)?:

a. Escape only (no rescue): Yes/No
b. Emergency rescue only: Yes/No
c. Less than 5 hours ***per week:*** Yes/No
d. Less than 2 hours ***per day:*** Yes/No
e. 2 to 4 hours per day: Yes/No
f. Over 4 hours per day: Yes/No

12. During the period you are using the respirator(s), is your work effort:

a. ***Light*** (less than 200 kcal per hour): Yes/No

If "yes," how long does this period last during the average shift: ___hrs.___mins.

Examples of a light work effort are ***sitting*** while writing, typing, drafting, or performing light assembly work; or ***standing*** while operating a drill press (1-3 lbs.) or controlling machines.

b. ***Moderate*** (200 to 350 kcal per hour): Yes/No

If "yes," how long does this period last during the average shift: ___hrs.___mins.

Examples of moderate work effort are ***sitting*** while nailing or filing; ***driving*** a truck or bus in urban traffic; ***standing*** while drilling, nailing, performing assembly work, or transferring a moderate load (about 35 lbs.) at trunk level; ***walking*** on a level surface about 2 mph or down a 5-degree grade about 3 mph; or ***pushing*** a wheelbarrow with a heavy load (about 100 lbs.) on a level surface.

c. ***Heavy*** (above 350 kcal per hour): Yes/No

If "yes," how long does this period last during the average shift: ___hrs.___mins.

Examples of heavy work are ***lifting*** a heavy load (about 50 lbs.) from the floor to your waist or shoulder; working on a loading dock; ***shoveling; standing*** while bricklaying or chipping castings; ***walking*** up an 8-degree grade about 2 mph; climbing stairs with a heavy load (about 50 lbs.).

13. Will you be wearing protective clothing and/or equipment (other than the respirator) when you're using your respirator: Yes/No

If "yes," describe this protective clothing and/or equipment:__________
____

14. Will you be working under hot conditions (temperature exceeding 77 deg. F): Yes/No

15. Will you be working under humid conditions: Yes/No

16. Describe the work you'll be doing while you're using your respirator(s):
____

17. Describe any special or hazardous conditions you might encounter when you're using your respirator(s) (for example, confined spaces, life-threatening gases):
____

18. Provide the following information, if you know it, for each toxic substance that you'll be exposed to when you're using your respirator(s):

- Name of the first toxic substance:____________________________________
- Estimated maximum exposure level per shift:___________________________
- Duration of exposure per shift:_______________________________________
- Name of the second toxic substance:__________________________________
- Estimated maximum exposure level per shift:___________________________
- Duration of exposure per shift:_______________________________________
- Name of the third toxic substance:____________________________________
- Estimated maximum exposure level per shift:___________________________
- Duration of exposure per shift:_______________________________________
- The name of any other toxic substances that you'll be exposed to while using your respirator:____

19. Describe any special responsibilities you'll have while using your respirator(s) that may affect the safety and well-being of others (for example, rescue, security):
____

Appendix B

Subject Characteristics

Table B1

Subject Characteristics N=18

Code #	**Gender**	**Age** years	**Height** centimeters	**Weight** kilograms	**Weight** Newtons
1	F	21	170.2	67.3	659.7
4	F	21	167.6	62.7	615.1
5	F	22	167.6	63.6	624.1
7	F	19	185.4	94.5	927.2
9	F	18	165.1	59.1	579.5
12	F	21	182.9	87.3	855.9
13	F	19	182.9	69.5	682.0
14	F	19	170.2	61.8	606.2
16	F	22	162.6	67.7	664.2
19	M	25	180.3	76.4	748.9
20	M	20	185.4	111.4	1092.1
21	M	22	172.7	97.7	958.4
23	M	22	185.4	80.5	789.0
26	M	20	193.0	82.3	806.8
27	M	21	175.3	69.1	677.6
28	M	22	175.3	84.1	824.7
31	M	22	188.0	97.7	958.4
32	M	25	182.9	84.1	824.7
Overall Mean		21.2	177.4	78.7	771.9
SD		1.8	8.7	14.6	143.0
Female Mean		20.2	172.7	70.4	690.4
SD		1.4	8.2	11.7	114.4
Male Mean		22.1	182.0	87.0	853.4
SD		1.8	6.4	12.4	121.3

Appendix C

Summary of Research Trial Periods, Durations, Activities, and Measurements

Table C1

Summary of Research Trial Periods, Durations, Activities, and Measurements

Period	Duration	Subject Activity	Measurements
Before Test	5 Minutes	Sit, review paperwork; prepare for trial	Resting HR, BP, %O2, lactate
Wingate Preparation and Protocol			
Warm-up	5 Minutes	Cycle at low resistance, at or below 50 rpm.	Continual HR, % O2.
Sprints	1-2 Minutes	Four 8-10-second sprints at ½ prescribed resistance. Brief rest between sprints.	Continual HR, % O2. HR, BP, %O2 at end of sprints
Sprint Recovery	5 Minutes	Cycle at low resistance, at or below 50 rpm	Continual HR, % O2. HR, BP, %O2 at end
Wingate Protocol	30 Seconds	Cycle at highest rpm possible against prescribed resistance	HR, BP, %O2, lactate after Wingate.
End of Wingate Protocol – Immediately begin MMSE			
MMSE	2-3 Minutes	Answer questions, perform tasks; pedal slowly at no/low resistance	Answers and times recorded and later evaluated by researcher
Cool Down	2-5 Minutes	Pedal slowly. Dismount ergometer at HR <120bpm, walk slowly 2 minutes, sit	HR, BP, %O2, lactate when pulse rate reaches 100 bpm.

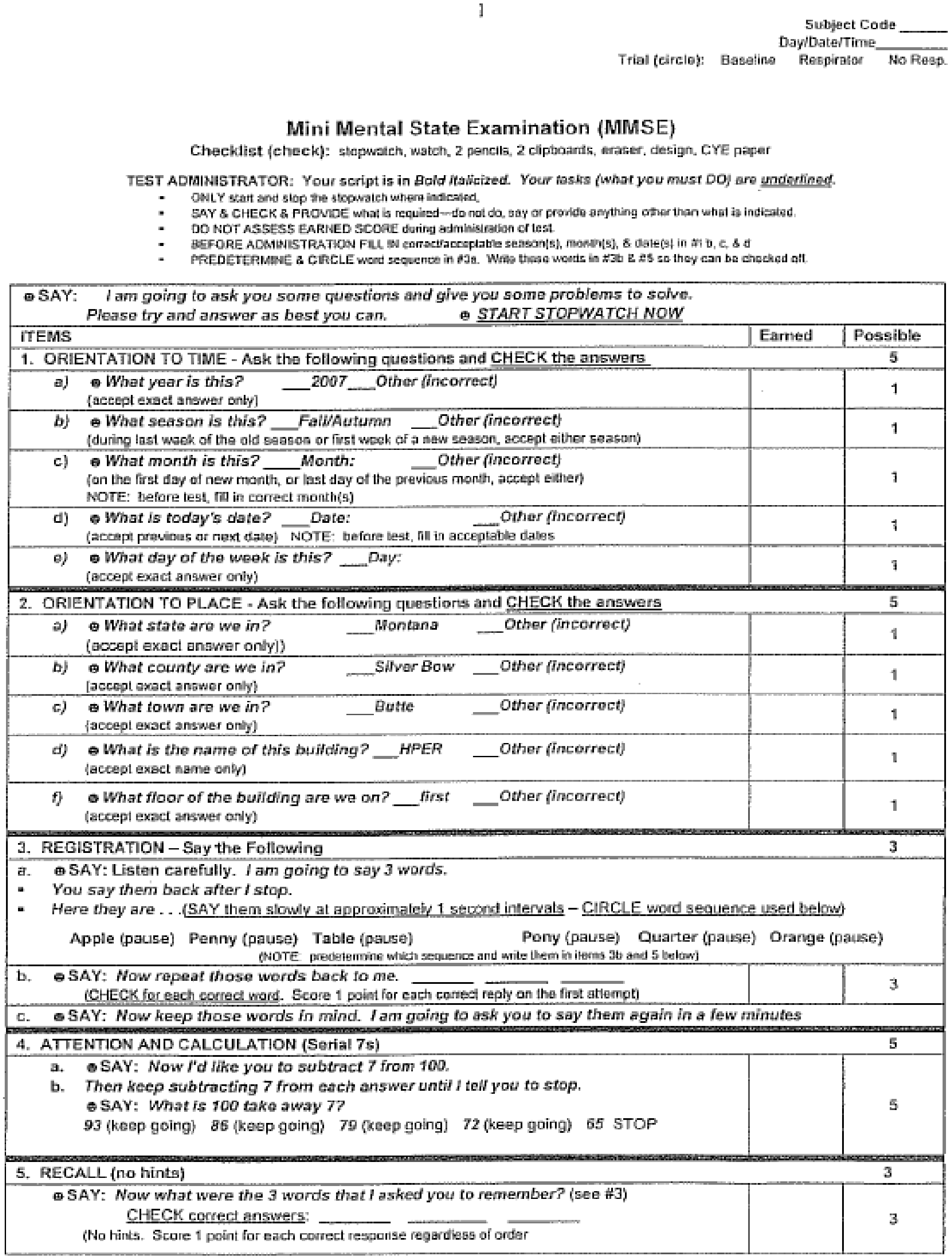
Appendix D

Mini Mental State Examination Data Collection Form

For data collection, the MMSE score sheets (pages 1 and 2) were oriented side-by-side in landscape configuration on one 8.5” x 17” piece of paper, sized, and arranged so that all questions fit on the front of one page affixed to a clipboard. The timer recorded times per individual section on a duplicate form. Times were transferred to the answer form at the end of the trial. All items were narrated to the subject, with items 9-11 requiring use of pages 3 and 4 of this appendix for reading, writing, and drawing. Original MMSE forms were adapted for one-stroke recording of answers to allow for rapid administration.

Figure D1

MMSE Data Form – Page 1



]

Subject Code ______
Day/Date/Time__________
Trial (circle): Baseline Respirator No Resp.

Mini Mental State Examination (MMSE)

Checklist (check): stopwatch, watch, 2 pencils, 2 clipboards, eraser, design, CYE paper

TEST ADMINISTRATOR: Your script is in ***Bold Italicized.*** *Your tasks (what you must DO) are underlined.*

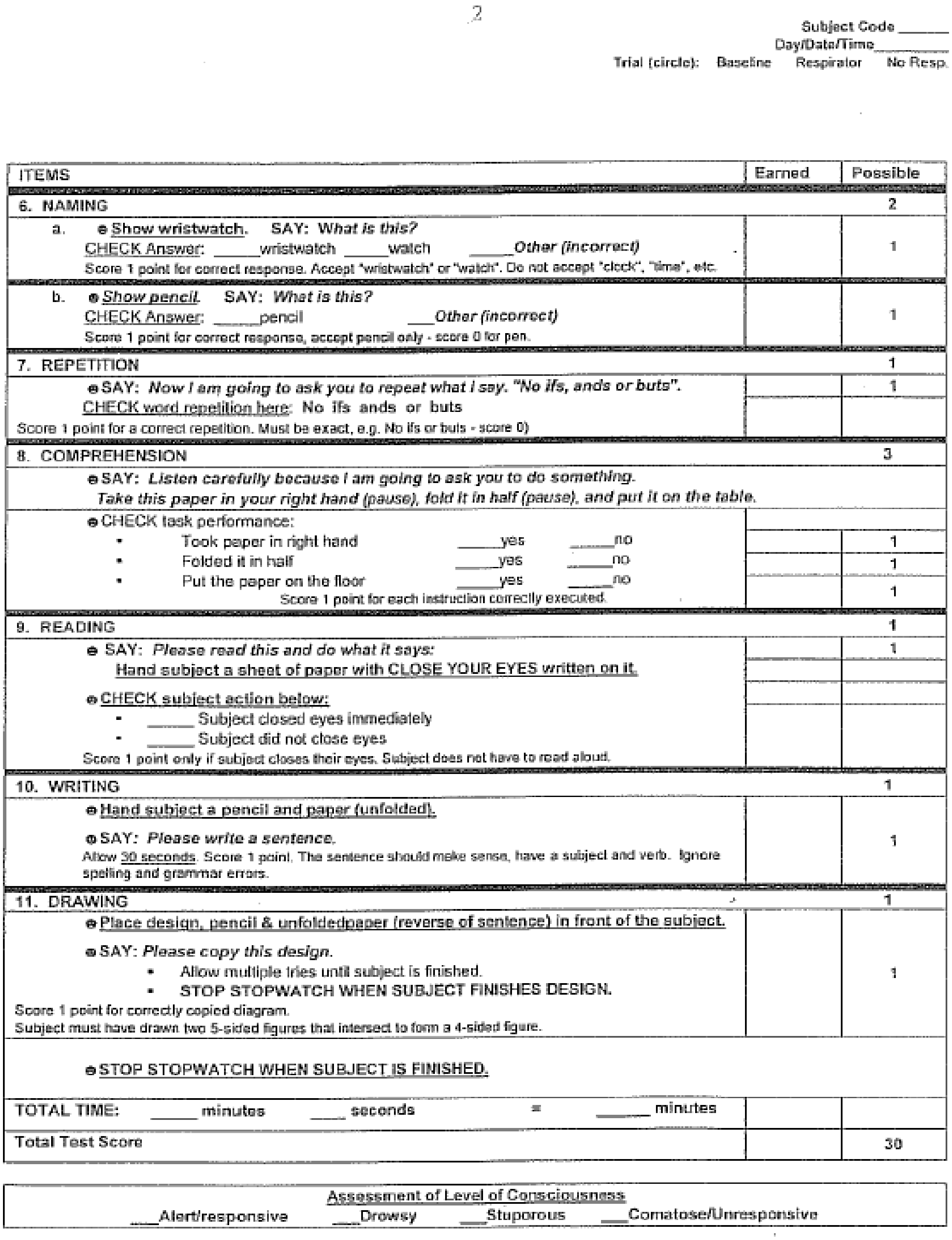
- ONLY start and stop the stopwatch where indicated.
- SAY & CHECK & PROVIDE what is required—do not do, say or provide anything other than what is indicated.
- DO NOT ASSESS EARNED SCORE during administration of test.
- BEFORE ADMINISTRATION FILL IN correct/acceptable season(s), month(s), & date(s) in #1 b, c, & d
- PREDETERMINE & CIRCLE word sequence in #3a. Write these words in #3b & #5 so they can be checked off.

☺ SAY: ***I am going to ask you some questions and give you some problems to solve.***
Please try and answer as best you can. ☺ ***START STOPWATCH NOW***

ITEMS	Earned	Possible
1. ORIENTATION TO TIME - Ask the following questions and CHECK the answers		5
a) ☺ ***What year is this?*** ___2007___Other (incorrect) (accept exact answer only)		1
b) ☺ ***What season is this?*** ___Fall/Autumn ___Other (incorrect) (during last week of the old season or first week of a new season, accept either season)		1
c) ☺ ***What month is this?*** ____Month: ___Other (incorrect) (on the first day of new month, or last day of the previous month, accept either) NOTE: before test, fill in correct month(s)		1
d) ☺ ***What is today's date?*** ___Date: ___Other (incorrect) (accept previous or next date) NOTE: before test, fill in acceptable dates		1
e) ☺ ***What day of the week is this?*** ___Day: (accept exact answer only)		1
2. ORIENTATION TO PLACE - Ask the following questions and CHECK the answers		5
a) ☺ ***What state are we in?*** ___Montana ___Other (incorrect) (accept exact answer only))		1
b) ☺ ***What county are we in?*** ___Silver Bow ___Other (incorrect) (accept exact answer only)		1
c) ☺ ***What town are we in?*** ___Butte ___Other (incorrect) (accept exact answer only)		1
d) ☺ ***What is the name of this building?*** ___HPER ___Other (incorrect) (accept exact name only)		1
f) ☺ ***What floor of the building are we on?*** ___first ___Other (incorrect) (accept exact answer only)		1
3. REGISTRATION – Say the Following		3
a. ☺ SAY: Listen carefully. ***I am going to say 3 words.*** ▪ ***You say them back after I stop.*** ▪ ***Here they are . . .***(SAY them slowly at approximately 1 second intervals – CIRCLE word sequence used below) Apple (pause) Penny (pause) Table (pause) Pony (pause) Quarter (pause) Orange (pause) (NOTE: predetermine which sequence and write them in items 3b and 5 below)		
b. ☺ SAY: ***Now repeat those words back to me.*** _______ _______ _______ (CHECK for each correct word. Score 1 point for each correct reply on the first attempt)		3
c. ☺ SAY: ***Now keep those words in mind. I am going to ask you to say them again in a few minutes***		
4. ATTENTION AND CALCULATION (Serial 7s)		5
a. ☺ SAY: ***Now I'd like you to subtract 7 from 100.*** b. ***Then keep subtracting 7 from each answer until I tell you to stop.*** ☺ SAY: ***What is 100 take away 7?*** *93* (keep going) *86* (keep going) *79* (keep going) *72* (keep going) *65* STOP		5
5. RECALL (no hints)		3
☺ SAY: ***Now what were the 3 words that I asked you to remember?*** (see #3) CHECK correct answers: _______ _______ _______ (No hints. Score 1 point for each correct response regardless of order		3

Figure D1 continued

MMSE Data Form – Page 2



2

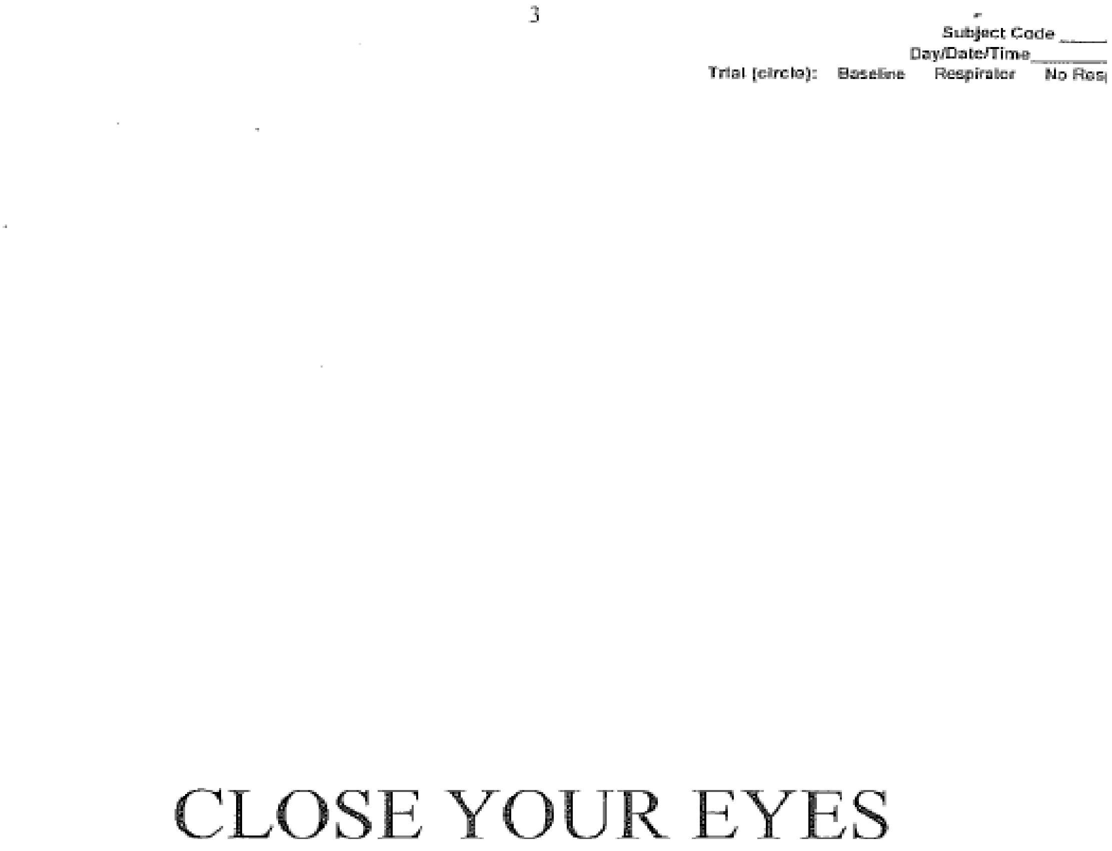
Subject Code ______
Day/Date/Time________
Trial (circle): Baseline Respirator No Resp.

ITEMS	Earned	Possible
6. NAMING		2
a. ⊖ Show wristwatch. SAY: *What is this?* CHECK Answer: _____wristwatch _____watch _____*Other (incorrect)* Score 1 point for correct response. Accept "wristwatch" or "watch". Do not accept "clock", "time", etc.		1
b. ⊖ *Show pencil.* SAY: *What is this?* CHECK Answer: _____pencil ___*Other (incorrect)* Score 1 point for correct response, accept pencil only - score 0 for pen.		1
7. REPETITION		1
⊖ SAY: *Now I am going to ask you to repeat what I say. "No ifs, ands or buts".* CHECK word repetition here: No ifs ands or buts Score 1 point for a correct repetition. Must be exact, e.g. No ifs or buts - score 0)		1
8. COMPREHENSION		3
⊖ SAY: *Listen carefully because I am going to ask you to do something.* *Take this paper in your right hand (pause), fold it in half (pause), and put it on the table.*		
⊖ CHECK task performance:		
• Took paper in right hand _____yes _____no		1
• Folded it in half _____yes _____no		1
• Put the paper on the floor _____yes _____no Score 1 point for each instruction correctly executed.		1
9. READING		1
⊖ SAY: *Please read this and do what it says:* Hand subject a sheet of paper with CLOSE YOUR EYES written on it.		1
⊖ CHECK subject action below: • _____ Subject closed eyes immediately • _____ Subject did not close eyes Score 1 point only if subject closes their eyes. Subject does not have to read aloud.		
10. WRITING		1
⊖ Hand subject a pencil and paper (unfolded). ⊖ SAY: *Please write a sentence.* Allow 30 seconds. Score 1 point. The sentence should make sense, have a subject and verb. Ignore spelling and grammar errors.		1
11. DRAWING		1
⊖ Place design, pencil & unfoldedpaper (reverse of sentence) in front of the subject. ⊖ SAY: *Please copy this design.* • Allow multiple tries until subject is finished. • STOP STOPWATCH WHEN SUBJECT FINISHES DESIGN. Score 1 point for correctly copied diagram. Subject must have drawn two 5-sided figures that intersect to form a 4-sided figure.		1
⊖ STOP STOPWATCH WHEN SUBJECT IS FINISHED.		
TOTAL TIME: _____ minutes ____ seconds = ______ minutes		
Total Test Score		30

Assessment of Level of Consciousness
___Alert/responsive ___Drowsy ___Stuporous ___Comatose/Unresponsive

Figure D1 continued

MMSE Data Form – Page 3



3

Subject Code ____
Day/Date/Time____
Trial (circle): Baseline Respirator No Res

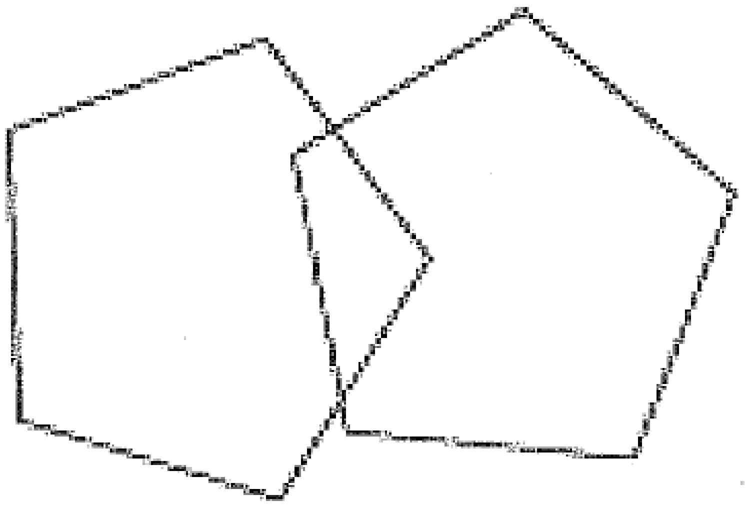
CLOSE YOUR EYES

Figure D1 continued

MMSE Data Form – Page 4

4

Subject Code ______
Day/Date/Time__________
Trial (circle): Baseline Respirator No Resp.



Appendix E

Summary Tables of Statistical Analysis Results for Each Response Variable

The following tables show the results of the Minitab Analysis of Variance (ANOVA) General Linear Model (GLM) for each response variable for which analysis was conducted. Analysis was not conducted for variables S2, S3, and S6-S11 because the scores within each of these sections did not change.

There is one summary table for each variable. The tables include the tabular results of one or more ANOVA. Subsequent ANOVA analyses were performed when one or more predictor variables showed statistical reliability ($p < .05$) and others did not. The non-significant factors were omitted one at a time from the model. After each omission, analysis was conducted to attain final significance. Where treatment was statistically reliable, Bonferroni 95% Confidence Intervals (CIs) were calculated to discern which treatment pairs were important.

The tables are sequenced by scores from S0 to S11, excluding S2, S3, and S6-S11, for which no changes occurred, followed by times from T0 to T11. Statistically reliable values are in **bold** font**.** In Table E1, the GLM summary of factors, their types, levels and values are listed. Under Values, the subject numbers are the codes assigned to each subject at the onset of the research.

Table E1

Minitab ANOVA GLM Analysis Factors

ANOVA General Linear Model Factors			
Factor	Type	Levels	Values
Treatment	Fixed	4	N, P, R, S
Gender	Fixed	2	F, M
Subject (Gender)	Random	18	1, 4, 5, 7, 9, 12, 13, 14, 16, 19, 20, 21, 23, 26, 27, 28, 31, 32

Table E2

MMSE Scores – S0 Total Scores Analysis

ANOVA #1 for S0 Total Scores using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	11.611	3.870	3.21	0.031
Gender	1	0.500	0.500	0.28	0.604
Treatment*Gender	3	2.056	0.685	0.57	0.638
Subject (Gender)	16	28.611	1.788	1.48	0.145
Error	48	57.833	1.205		
Total	71	100.611			
S = 1.09766	R-Sq = 42.52%		R-Sq(adj) = 14.97%		

ANOVA #2 for S0 Total Scores using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	11.611	3.870	3.30	0.028
Gender	1	0.500	0.500	0.28	0.604
Subject (Gender)	16	28.611	1.788	1.52	0.128
Error	51	59.889	1.174		
Total	71	100.611			
S = 1.08365	R-Sq = 40.47%		R-Sq(adj) = 17.13%		

Note. Treatment*Gender was removed for this analysis.

ANOVA #3 for S0 Total Scores using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	**P**
Treatment	3	11.611	3.870	2.96	**0.038**
Error	68	89.000	1.309		
Total	71	100.611			
S = 1.14404	R-Sq = 11.54%		R-Sq(adj) = 7.64%		

Note. Gender and Subject (Gender) were removed for this analysis.

Bonferroni 95% CIs for S0 Total Scores Treatment Comparisons

Treatment Pair	**Interval**
N-P	[-0.6027, 1.380]
N-R	**[0.1195, 2.103]**
N-S	[-0.3805, 1.603]
P-R	[-0.2693, 1.714]
P-S	[-0.7693, 1.214]
R-S	[-1.492, 0.4916]

Table E3

MMSE Scores – S1 Orientation to Time Analysis

ANOVA #1 for S1 Orientation to Time using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	2.0417	0.6806	3.92	0.014
Gender	1	0.3472	0.3472	2.00	0.176
Treatment*Gender	3	0.3750	0.1250	0.72	0.545
Subject (Gender)	16	2.7778	0.1736	1.00	0.473
Error	48	8.333	0.1736		
Total	71	13.8750			
S = 0.416667	R-Sq = 39.94%		R-Sq(adj) = 11.16%		

ANOVA #2 for S1 Orientation to Time using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	2.0417	0.6806	3.99	0.013
Gender	1	0.3472	0.3472	2.00	0.176
Subject (Gender)	16	2.7778	1.736	1.02	0.456
Error	51	8.7083	1.708		
Total	71	13.8750			
S = 0.413221	R-Sq = 37.24%		R-Sq(adj) = 12.62%		

Note. Treatment*Gender was removed for this analysis.

ANOVA #3 for S1 Orientation to Time using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	**P**
Treatment	3	2.0417	0.6806	3.91	**0.012**
Error	68	11.8333	0.1740		
Total	71	13.8750			
S = 0.417157	R-Sq = 14.71%		R-Sq(adj) = 10.95%		

Note. Gender and Subject (Gender) were removed for this analysis.

Bonferroni 95% CIs for S1 Orientation to Time Treatment Comparisons

Treatment Pair	**Interval**
N-P	[-0.0446, 0.7112]
N-R	**[0.0666, 0.8223]**
N-S	[-0.2112, 0.5446]
P-R	[-0.2668, 0.4890]
P-S	[-0.5446, 0.2112]
R-S	[-0.6557, 0.1001]

Table E4

MMSE Scores – S4 Attention and Calculation Analysis

ANOVA for S4 Attention and Calculation using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	3.3889	1.1296	1.90	0.142
Gender	1	0.8889	0.8889	0.87	0.365
Treatment*Gender	3	0.1111	0.0370	0.06	0.979
Subject (Gender)	16	16.3889	1.0243	1.73	0.074
Error	48	28.5000	0.5937		
Total	71	49.2778			
S = 0.770552	R-Sq = 42.16%		R-Sq(adj) = 14.45%		

Table E5

MMSE Scores – S5 Recall Analysis

ANOVA for S5 Recall using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	1.1528	0.3843	1.43	0.245
Gender	1	0.6806	0.6806	1.96	0.181
Treatment*Gender	3	0.7083	0.2361	0.88	0.458
Subject (Gender)	16	5.5556	0.3472	1.29	0.240
Error	48	12.8889	0.2685		
Total	71	20.9861			
S = 0.518188	R-Sq = 38.58%		R-Sq(adj) = 9.16%		

Table E6

MMSE Times – T0 Total Times Analysis

ANOVA #1 for T0 Total Times using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	6106.39	2035.46	21.95	0.000
Gender	1	4324.50	4324.50	13.64	0.002
Treatment*Gender	3	482.83	160.94	1.74	0.172
Subject (Gender)	16	5072.94	317.06	3.42	0.000
Error	48	4451.28	92.73		
Total	71	20437.94			
S = 9.62990	R-Sq = 78.22%		R-Sq(adj) = 67.78%		

ANOVA #2 for T0 Total Times using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	**P**
Treatment	3	6106.39	2035.46	21.04	**0.000**
Gender	1	4324.50	4324.50	13.64	**0.002**
Subject (Gender)	16	5072.94	317.06	3.28	**0.001**
Error	51	4394.11	96.75		
Total	71	20437.94			
S = 9.83602	R-Sq = 75.86%		R-Sq(adj) = 66.39%		

Note. Treatment*Gender was removed for this analysis.

Bonferroni 95% CIs for T0 Total Times Treatment Comparisons

Treatment Pair	**Interval**
N-P	[-15.22, 2.78]
N-R	**[-27.00, -9.00]**
N-S	**[-32.22, -14.22]**
P-R	**[-20.78, -2.778]**
P-S	**[-26.00, -8.00]**
R-S	[-1.492, 0.4916]

Table E7

MMSE Times – T1 Orientation to Time Analysis

ANOVA for T1 Orientation to Time using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	31.042	10.347	1.50	0.227
Gender	1	17.014	17.014	1.84	0.194
Treatment*Gender	3	19.042	6.347	0.92	0.439
Subject (Gender)	16	148.111	9.257	1.34	0.213
Error	48	331.667	6.910		
Total	71	546.875			
S = 2.62864	R-Sq = 39.35%		R-Sq(adj) = 10.29%		

Table E8

MMSE Times – T2 Orientation to Place Analysis

ANOVA #1 for T2 Orientation to Place using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	60.167	20.056	6.86	0.001
Gender	1	10.889	10.889	2.79	0.115
Treatment*Gender	3	8.000	2.667	0.91	0.442
Subject (Gender)	16	62.556	3.910	1.34	0.215
Error	48	140.333	2.924		
Total	71	281.944			
S = 1.70986	R-Sq = 50.23%		R-Sq(adj) = 26.38%		

ANOVA #2 for T2 Orientation to Place using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	60.167	20.056	6.90	0.001
Gender	1	10.889	10.889	2.79	0.115
Subject (Gender)	16	62.556	3.910	1.34	0.208
Error	51	148.333	2.908		
Total	71	281.944			
S = 1.70543	R-Sq = 47.39%		R-Sq(adj) = 26.76%		

Note. Treatment*Gender was removed for this analysis.

ANOVA #3 for T2 Orientation to Place using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	**P**
Treatment	3	60.167	20.056	6.90	**0.001**
Subject	17	73.444	4.320	1.49	0.138
Error	51	148.333	2.908		
Total	71	281.944			
S = 1.70543	R-Sq = 47.39%		R-Sq(adj) = 26.76%		

Note. Gender was removed for this analysis.

Bonferroni 95% CIs for T2 Orientation to Place Treatment Comparisons

Treatment Pair	**Interval**
N-P	[-2.192, 1.0804]
N-R	**[-3.303, -0.307]**
N-S	**[-3.969, -0.6974]**
P-R	[-2.747, -0.5249]
P-S	**[-3.414, -0.1418]**
R-S	[-2.303, 0.9693]

Table E9

MMSE Times – T3 Registration Analysis

ANOVA #1 for T3 Registration using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	102.71	32.24	2.98	0.041
Gender	1	0.01	0.01	0.00	0.970
Treatment*Gender	3	3.37	1.12	0.10	0.961
Subject (Gender)	16	151.39	9.46	0.82	0.655
Error	48	552.17	11.50		
Total	71	809.65			
S = 3.39168	R-Sq = 31.80%		R-Sq(adj) = 0.00%		

ANOVA #2 for T3 Registration using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	102.71	34.24	3.14	0.033
Gender	1	0.01	0.01	0.00	0.970
Subject (Gender)	16	151.39	9.46	0.87	0.606
Error	51	555.54	10.89		
Total	71	809.65			
S = 9.83602	R-Sq = 31.39%		R-Sq(adj) = 4.48%		

ANOVA #3 for T3 Registration using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	102.71	34.24	3.14	0.033
Subject	17	151.40	8.91	0.82	0.666
Error	51	555.54	10.89		
Total	71	809.65			
S = 3.30045	R-Sq = 31.39%		R-Sq(adj) = 4.48%		

ANOVA #4 for T3 Registration using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	**P**
Treatment	3	102.71	34.24	3.29	**0.026**
Error	68	706.94	10.40		
Total	71	809.65			
S = 9.83602	R-Sq = 12.69%		R-Sq(adj) = 8.83%		

Bonferroni 95% CIs for T3 Treatment Comparisons

Treatment Pair	**Interval**
N-P	[-3.088, 2.75417]
N-R	[-4.143, 1.69862]
N-S	**[-5.921, -0.07916]**
P-R	[-3.976, 1.86528]
P-S	[-5.754, 0.8751]
R-S	[-4.699, 1.143]

Table E10

MMSE Times – T4 Attention and Calculation Analysis

ANOVA #1 for T4 Attention and Calculation using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	149.93	49.98	1.11	0.354
Gender	1	2189.01	2189.01	23.80	0.000
Treatment*Gender	3	64.60	21.53	0.48	0.699
Subject (Gender)	16	1471.61	91.98	2.04	0.029
Error	48	2159.72	44.99		
Total	71	6034.88			
S = 6.70777	R-Sq = 64.21%		R-Sq(adj) = 47.06%		

ANOVA #2 for T4 Attention and Calculation using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	149.93	49.98	1.15	0.340
Gender	1	2189.01	2189.01	23.80	**0.000**
Subject (Gender)	16	1471.61	91.98	2.11	**0.023**
Error	51	2224.32	43.61		
Total	71	6034.88			
S = 6.60410	R-Sq = 63.14%		R-Sq(adj) = 48.69%		

Note. Treatment*Gender was removed for this analysis.

Table E11

MMSE Times – T5 Recall Analysis

ANOVA #1 for T5 Recall using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	19.486	6.495	2.17	0.104
Gender	1	0.681	0.681	0.21	0.650
Treatment*Gender	3	4.486	1.495	0.50	0.685
Subject (Gender)	16	50.889	3.181	1.06	0.415
Error	48	143.778	2.995		
Total	71	219.319			
S = 1.73071	R-Sq = 34.44%		R-Sq(adj) = 3.03%		

Table E12

MMSE Times – T6 Naming Analysis

ANOVA #1 for T6 Naming using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	4.819	1.606	1.18	0.329
Gender	1	0.014	0.014	0.01	0.923
Treatment*Gender	3	7.375	2.458	1.80	0.160
Subject (Gender)	16	23.111	1.444	1.06	0.419
Error	48	65.556	1.366		
Total	71	100.875			
S = 1.16865	R-Sq = 35.01%		R-Sq(adj) = 3.87%		

Table E13

MMSE Times – T7 Repetition Analysis

ANOVA #1 for T7 Repetition using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	14.708	4.903	2.68	0.057
Gender	1	0.681	0.681	0.28	0.602
Treatment*Gender	3	4.264	1.421	0.78	0.512
Subject (Gender)	16	38.444	2.403	1.31	0.228
Error	48	87.778	1.829		
Total	71	145.875			
S = 1.35230	R-Sq = 39.83%		R-Sq(adj) = 10.99%		

Table E14

MMSE Times – T8 Comprehension Analysis

ANOVA #1 for T8 Comprehension using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	136.60	45.53	2.57	0.065
Gender	1	30.68	30.68	2.46	0.137
Treatment*Gender	3	25.82	8.61	0.49	0.694
Subject (Gender)	16	199.94	12.50	0.71	0.774
Error	48	849.83	17.70		
Total	71	1242.87			
S = 4.20771	R-Sq = 31.62%		R-Sq(adj) = 0.00%		

Table E15

MMSE Times – T9 Reading Analysis

ANOVA #1 for T9 Reading using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	16.375	5.458	1.11	0.354
Gender	1	6.125	6.125	1.11	0.309
Treatment*Gender	3	24.819	8.273	1.68	0.183
Subject (Gender)	16	88.611	5.538	1.13	0.360
Error	48	236.056	4.918		
Total	71	371.986			
S = 2.21762	R-Sq = 36.54%		R-Sq(adj) = 6.13%		

Table E16

MMSE Times – T10 Writing Analysis

ANOVA #1 for T10 Writing using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	24.111	8.037	1.58	0.207
Gender	1	6.722	6.722	0.56	0.465
Treatment*Gender	3	41.611	13.870	2.73	0.054
Subject (Gender)	16	192.389	12.024	2.36	0.011
Error	48	244.278	5.089		
Total	71	509.111			
S = 2.25591	R-Sq = 52.02%		R-Sq(adj) = 29.03%		

ANOVA #2 for T10 Writing using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	24.111	8.037	1.43	0.244
Gender	1	6.722	6.722	0.56	0.465
Subject (Gender)	16	192.389	12.024	2.15	**0.020**
Error	51	285.899	5.606		
Total	71	509.111			
S = 1.70543	R-Sq = 43.85%		R-Sq(adj) = 21.82%		

Note. Treatment*Gender was removed for this analysis.

Table E17

MMSE Times – T11 Drawing Analysis

ANOVA #1 for T11 Drawing using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	324.94	108.31	5.57	0.002
Gender	1	34.72	34.72	0.95	0.344
Treatment*Gender	3	10.94	3.65	0.19	0.904
Subject (Gender)	16	584.56	36.53	1.88	0.047
Error	48	934.11	19.46		
Total	71	1889.28			
S = 4.41142	R-Sq = 50.56%		R-Sq(adj) = 26.87%		

ANOVA #2 for T11 Drawing using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	P
Treatment	3	324.94	108.31	5.85	0.002
Gender	1	34.72	34.72	0.95	0.344
Subject (Gender)	16	584.56	36.53	1.97	0.034
Error	51	945.06	18.53		
Total	71	1889.28			
S = 1.70543	R-Sq = 49.98%		R-Sq(adj) = 30.36%		

Note. Treatment*Gender was removed for this analysis.

ANOVA #3 for T11 Drawing using Sequential SS

Source	DF	Sequential SS	Sequential MS	F	**P**
Treatment	3	324.94	108.31	5.85	**0.002**
Subject	17	619.28	36.43	1.97	**0.033**
Error	51	945.06	18.53		
Total	71	1889.28			
S = 4.30471	R-Sq = 49.98%		R-Sq(adj) = 30.36%		

Note. Gender was removed for this analysis.

Bonferroni 95% CIs for T11 Drawing Treatment Comparisons

Treatment Pair	**Interval**
N-P	[-6.161, 1.717]
N-R	**[-8.217, -0.339]**
N-S	**[-9.550, -1.672]**
P-R	[-5.994, 1.8834]
P-S	[-7.328, 0.5500]
R-S	[-5.272, 2.606]

Appendix F

Matrices Summarizing Score and Time Results for All Variables

Tables F1 for MMSE scores and F2 for MMSE times assemble the findings of this study in a collated format that integrates various aspects of treatment (N, P, R, S), gender (F, M), and subject effect. Statistical results, means and standard deviations, and treatment order are shown. The following information will assist in interpreting these tables:

1. Statistically reliable *p* values are in **bold** font.
2. Statistically significant treatment pairs are noted in the treatment column.
3. Direction of treatment and gender effect are indicated with greater than or less than (< >) symbols.
4. The greatest overall, male, and female scores (positive effect) and times (negative effect) for each variable are in **bold** font and lowest scores (negative effect) and times (positive effect) are underlined.
5. Positive gender effect is indicated by blue (male) or pink (female) cells for the gender with the highest overall scores or lowest overall times. White cells indicate equality.
6. The greatest positive effects (highest scores and lowest times) for each treatment, both overall and for each gender, are highlighted in yellow.
7. To compare statistical reliability between score and time categories for each variable, an asterisk (*) indicates variables showing significance in the other category—significant times are asterisked in Table F1 for scores, and significant scores are asterisked in Table F2 for times.

Table F1

Matrix of Score P values, Means, Effect and Treatment Order for Treatment, Gender, Interaction and Subject

SCORE Variable	**P values from 2-way ANOVA GLM**				**Overall and Gender-Specific Mean Scores, Overall Standard Deviations**					**Treatment Order** **High (+)** to Low (-)
	Treatment (Sig. pairs)	**Gender**	**Treatment x Gender**	**Subject**	**N** **Mean (SD)** **F M**	**P** **Mean (SD)** **F M**	**R** **Mean (SD)** **F M**	**S** **Mean (SD)** **F M**	**Overall** **Mean (SD)** **F M**	
S0 *	* **.038** (R > N)	* .604	.638	* .128	*28.3* (1.2) *28.0* < *28.6*	28.6 (1.3) 28.4 < 28.7	**29.4** (0.6) **29.6** > **29.2**	28.7 (1.4) 28.6 < 28.9	28.9 (1.2) 28.8 < 28.9	R>S>P>N
S1 *	**.012** (R > N)	.176	.545	.456	*4.6* (0.5) *4.4* < *4.7*	4.9 (0.3) 4.9 = 4.9	**5.0** (0.0) **5.0 = 5.0**	4.8 (0.6) 4.7 < 4.9	4.8 (0.4) 4.7 < 4.9	R>P>S>N
S2 *	*				5.0 (0.0) 5.0 5.0	5.0 (0.0) 5.0 5.0	5.0 (0.0) 5.0 5.0	5.0 (0.0) 5.0 5.0	5.0 (0.0) 5.0 5.0	
S3					3 .0 (0.0) 3.0 3.0	3 .0 (0.0) 3.0 3.0	3 .0 (0.0) 3.0 3.0	3 .0 (0.0) 3.0 3.0	3 .0 (0.0) 3.0 3.0	
S4 *	.142	* .365	.979	* .074	*4.0* (0.8) *3.9* < *4.1*	4.3 (0.9) 4.1 < 4.4	**4.6** (0.3) **4.6** < **4.7**	4.3 (1.0) 4.2 < 4.4	4.3 (0.8) 4.2 < 4.4	R>P=S>N
S5	.245	.181	.458	.240	2.8 (0.4) *2.8* = 2.8	*2.6* (0.9) *2.8* > *2.3*	2.8 (0.4) **3.0** > 2.7	**2.9** (0.3) 2.9 = **2.9**	2.8 (0.3) 2.9 > 2.7	S>R=N>P
S6	For dependent variables S2, S3, and S6-S11, no score differences occurred. Therefore, no statistical analysis was conducted.				2 .0 (0.0) 2.0 2.0	2 .0 (0.0) 2.0 2.0	2 .0 (0.0) 2.0 2.0	2 .0 (0.0) 2.0 2.0	2 .0 (0.0) 2.0 2.0	
S7					1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	
S8					3 .0 (0.0) 3.0 3.0	3 .0 (0.0) 3.0 3.0	3 .0 (0.0) 3.0 3.0	3 .0 (0.0) 3.0 3.0	3 .0 (0.0) 3.0 3.0	
S9					1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	
S10 *				*	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	
S11 *	*			*	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	1 .0 (0.0) 1.0 1.0	
Note. * MMSE section for which time was statistically reliable					F < M = 25% F > M = 0 F = M = 75%	F < M = 16.7% F > M = 8.3% F = M = 75%	F < M = 8.3% F > M = 16.7% F = M = 75%	F < M = 25%0 F > M = 0 F = M = 75%	F < M = 25% F > M = 8.3% F = M = 66.7%	

Table F2

Matrix of Time P values, Means, Effect and Treatment Order for Treatment, Gender, Interaction and Subject

TIME Variable	**P values from 2-way ANOVA GLM**				**Overall and Gender-Specific Mean Times, Overall Standard Deviations**					**Treatment Order** High (-) to Low (+)
	Treatment (Sig. pairs)	**Gender**	**Treatment * Gender**	**Subject**	**N Mean (SD)** F M	**P Mean (SD)** F M	**R Mean (SD)** F M	**S Mean (SD)** F M	**Overall Mean (SD)** F M	
T0 *	* **.000** (N>R, N>S, P>R, P>S)	**.002** F > M	.338	**.001**	**127.8** (17.7) **139.3** > **116.3**	121.6 (15.3) 130.0 > 113.2	109.8 (12.2) 116.6 > 103.1	*104.6* (12.2) *109.0 > 100.2*	116 (17.0) 123.7 > 108.2	N>P>R>S
T1 *	* .227	.194	.439	.213	**14.1** (2.7) **14.0 < 14.1**	13.0 (2.4) **14.0** > 12.0	12.9 (4.4) *12.9* = 12.9	*12.2* (2.7) 13.2 > *11.2*	13.0 (2.8) 13.5 > 12.6	N>P>R>S
T2	**.001** (N>R, N>S, P>S)	.115	.442	.138	**12.2** (2.3) 12.4 **> 11.9**	11.6 (1.5) **12.6** > 10.7	10.5 (1.7) 10.8 > 10.2	*9.8* (1.6) *9.9 > 9.8*	11.0 (2.0) 11.4 > 10.6	N>P>R>S
T3	**.026** (N>S)	.970	.961	.666	**10.7** (5.6) **10.7 = 10.7**	10.5 (2.3) 10.8 > 10.2	9.4 (1.8) 9.1 < 9.8	*7.7* (1.2) *7.7 = 7.7*	9.6 (3.6) 9.6 = 9.6	N>P>R>S
T4	.340	**.000** F > M	.699	**.023**	**27.9** (11.1) **35.0** > 20.8	26.1 (8.4) 30.8 > **21.4**	24.6 (8.2) 29.9 > 19.3	*24.2* (9.3) *29.2 > 19.2*	25.7 (9.2) 31.2 > 20.2	N>P>R>S
T5	.104	.650	.685	.415	5.2 (2.0) 5.0 < 5.4	**5.8** (2.2) **6.1** > 5.4	5.3 (1.2) 5.0 < **5.6**	*4.3* (1.2) *4.1 < 4.6*	5.2 (1.8) 5.1 < 5.3	P>R>N>S
T6	.329	.923	.160	.419	5.3 (1.5) **5.9** > *4.8*	**5.7** (1.4) 5.4 < **5.9**	*5.0* (1.0) *4.9* < 5.0	5.2 (0.7) 5.0 < 5.4	5.3 (1.2) 5.3 = 5.3	P>N>S>R
T7	.057	.602	.512	.228	**7.2** (1.5) **7.3** > **7.0**	6.6 (1.8) 7.0 > *6.1*	6.6 (0.7) 6.6 = 6.6	*5.9* (1.3) *5.7 < 6.1*	6.5 (1.4) 6.6 > 6.4	N>P=R>S
T8	.065	.137	.694	.774	14.2 (7.1) **15.9** > 12.6	**14.4** (2.6) 14.9 > **14.0**	*11.6* (1.6) *11.7* > 11.4	*11.6* (2.3) 12.0 > *11.2*	13.0 (4.2) 13.6 > 12.3	P>N>R=S
T9	.354	.309	.183	.360	**5.0** (2.2) **5.3** > 4.7	4.3 (2.5) 4.0 < 4.7	*3.7* (1.0) 3.8 > *3.7*	4.0 (3.0) *2.8* < **5.2**	4.3 (2.3) 4.0 < 4.6	N>P>S>R
T10	.244	.465	.054	**.020**	**10.8** (3.7) **12.2** > 9.3	10.5 (2.6) 10.6 > 10.4	*9.3* (1.3) 9.7 > *8.9*	9.9 (2.5) *9.2* < **10.6**	10.1 (2.7) 10.4 > 9.8	N>P>S>R
T11	**.002** (N>R, N>S)	.344	.904	**.034**	**15.3** (8.4) **15.6** > **15.1**	13.1 (3.1) 13.9 > 12.3	11.1 (2.4) 12.3 > 9.8	*9.7* (2.5) *10.2 > 9.2*	12.3 (5.2) 13.0 > 11.6	N>P>R>S
Note. * MMSE section for which score was statistically reliable					F > M = 75% F < M = 16.7% F = M = 8.3%	F > M = 83.3% F < M = 16.7% F = M = 0	F > M = 58.3% F < M = 25% F = M = 16.7%	F > M = 50% F < M = 41.7% F = M = 8.3%	F > M = 66.7% F < M = 16.7% F = M = 16.7%	