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Effects of Age on Cognitive Performance While Sitting and Walking at a Treadmill Workstation

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EFFECTS OF AGE ON COGNITIVE PERFORMANCE WHILE SITTING AND

WALKING AT A TREADMILL WORKSTATION

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EFFECTS OF AGE ON COGNITIVE PERFORMANCE WHILE SITTING AND WALKING AT A TREADMILL WORKSTATION

AUDREY ELIZABETH KING

ABSTRACT

Purpose: This study compared cognitive function and age using the Stroop test while sitting and while walking at a self-selected speed at a treadmill work station.

Methods: 50 subjects aged 20-69 years completed the Stroop test while sitting and while walking at a self-selected speed at a treadmill workstation. A repeated measures ANOVA was conducted to analyze for an interaction between age and cognition.

Results: The results showed a significant increase in reaction time as age increased ($p<.01$). The results also showed no significant difference in reaction time for any age group between sitting and walking ($p>.05$).

Conclusion: As individuals age there is an expected increase in cognitive and motor function and an increase in reaction time, those limitations are not significantly increased by adding a simultaneous motor task. Heart rate was also recorded during testing. Heart rate rose significantly while walking; however, this increase did not meet ACSM guidelines to improve cardiovascular endurance. While individuals will reap the benefits of increased caloric expenditure, there is no evidence of other benefits to the cardiovascular system.

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CHAPTER I

INTRODUCTION

Obesity has risen dramatically in the United States. A 2013-14 survey showed an obesity rate of 35% among men and 40% among women; for women this survey also showed a significant linear trend from 2005 (Flegal, Kruszon-Moran, Carroll, Fryar and Ogden, 2014). Several health risks are a result of obesity and sedentary lifestyles such as certain cancers, cardiovascular disease, and diabetes (McArdle, Katch and Katch, 2015). One way to help prevent these health problems is to increase physical activity.

Sedentary lifestyles are on the rise due to an increase in technology and jobs that require long days sitting behind a computer, preventing workers from meeting basic physical activity guidelines. The 2008 Centers for Disease Control (CDC) and Prevention guidelines recommend 150 minutes/week of moderate-intensity aerobic activity for substantial health benefits when compared to a sedentary lifestyle (CDC, 2018). Meeting these guidelines will help increase total energy expenditure which can in turn, decrease body fat, and the associated health risks. Several companies have implemented workplace physical activity programs such as on-site fitness centers, yoga classes, or weight loss challenges to benefit their employees. Increasing physical activity at work is not only beneficial to the individual, but also to the employer. Participation in wellness programs in the work place have been shown to lower health care costs (Naydeck, Pearson, Ozminkowski, Day and Goetzel, 2008). When companies invest in ways to keep their employees healthy, they end up saving money that would have been spent on health care.

Another way to combat a sedentary workplace is through exercise workstations, such as treadmill desks. Treadmill desks have been shown to increase daily minutes of physical activity and weight loss when used in the workplace (Koepp et al., 2013). While this can increase physical activity levels, there is also a potential loss of productivity if a worker loses dexterity while using a treadmill workstation, such as when typing or manipulating a mouse. However, workers have been shown to acclimate to these work conditions through practice which increases performance (MacEwan, MacDonald and Burr, 2014).

Age also factors into the ability of an individual to multitask at the work place. Decreases in cognitive function, executive function and control, as well as gait control, have been attributed to aging (Decker et al., 2015). All of these functions play a major role in completing cognitive tasks while walking. Older individuals may have a more difficult time adjusting to treadmill desks. However, age related mental decline may be slowed by maintaining a healthy body weight and staying active (MacEwan et al., 2014). A natural decline in both physical and cognitive function will occur in the workplace as employees age but maintaining high levels of physical activity can slow this decline. The question arises, to what extent will age affect cognitive function when transitioning from sitting to walking in workplace conditions?

Purpose of the Study

The purpose of this study was to observe how age affects reaction time and cognitive function while sitting and walking at a treadmill workstation.

Hypotheses

- Reaction time will be significantly higher in older individuals.
- Reaction time from sitting to walking at a treadmill workstation will be significantly higher in older individuals.
- Cognitive function from sitting to walking at a treadmill workstation will be significantly decline in older individuals.

Significance of Study

Working adults typically work for eight hour periods at a time, most of this time is spent in front of a computer. Long periods of sedentary activity can have serious negative effects on physical and mental health. However, while at work, individuals can work and walk at treadmill workstations to meet American College of Sports Medicine (ACSM, 2016) weekly recommendations and decrease their overall risk of sedentary diseases.

Delimitations

- Subjects were ages of 20 to 69 years.
- Subjects who were colorblind were excluded.
- Subjects had the physical ability to walk at a treadmill workstation.

CHAPTER II

LITERATURE REVIEW

Physical Activity and Long-Term Cognition

Being physically active throughout a lifetime has been shown to positively affect cognition. In a 2015 study, Holmes analyzed the relationship between fitness levels and cognitive performance among older adults. 41 Caucasian men and women, aged 65 to 90 years, from a retirement community were asked to complete the Physical Activity Scale for the Elderly (PASE), the Senior Fitness Test (SFT), the Late-Life Function and Disability Instrument (LL-FDI), and the Geriatric Immediate Post Concussion Assessment and Cognitive Test (IMPACT) to measure physical activity and fitness levels, as well as cognitive function. A moderate, positive correlation was found between the chair stand test (r=-.58 color match; r=-.51 clock speed, r=.52 shopping list) and the 8-foot-up-and-go test (r=-.51 design rotation; r==.61 shopping list; r==.80 traffic light) of the SFT with IMPACT scores; this indicates a positive relationship between functional fitness and cognitive function. A moderate, positive correlation was also found between PASE and the design rotation test (r=.55) and the traffic light test (r=.46) of the IMPACT scores; this indicates a positive relationship between self-reported physical activity levels and cognitive function (Holmes, 2015). This shows that the more time an individual spends on physical activity per day, the higher their functional fitness and neurocognitive performance.

Simple activities, such as walking, can lead to benefits associated with increased physical activities levels. Weuve (2004) found in a 28 year longitudinal study that a minimum of 90 minutes a week walking, at a 21-30 min/mile pace, led to increased cognitive function in women. This study consisted of 18,766 female nurses aged 70-81 years selected from the 1976 Nurse's Health Study. In 1986 the subjects first completed a baseline questionnaire to assess average energy expenditure and cognition. Starting in 1995, phone interviews assessed physical activity levels and cognition using the Telephone Interview for Cognitive Status (TICS) on a biennial basis until 2001. The results showed that the higher the activity level, the higher the scores on cognitive tasks. Comparing subjects in the second through fifth quintile of physical activity to the lowest quintile, cognition was significantly higher. Subjects who walked 90 minutes per week scored significantly better than those who only walked 40 minutes per week. Comparing the highest quintile to the lowest quintile, those who were most active were 20% less likely to run the risk of cognitive impairment (Weuve, 2004). This study showed a positive association between levels of lifetime physical activity and cognition. It also showed that impaired cognitive function at baseline was associated with decreases in physical activity levels over time.

Yaffe, Barnes, Nevitt, Lui, and Covinsky (2001) found similar results in an eight-year longitudinal study of 5,925 women (age $\geq$ 65 years) to analyze the relationship between physical activity and cognitive decline. Physical activity level was measured with self-report surveys on distance walked per week, while cognitive decline was measured with the Mini-Mental State Examination (MMSE) at six and eight years from baseline. The results showed that women in the highest quartile of number of blocks walked per week (113-672 blocks) had an average cognitive decline of 16.6%, while women in the lowest quartile (0-22 blocks) had a significantly higher average cognitive decline of 24.0% (Yaffe et al., 2001). These studies show that low-intensity exercise performed over a lifetime can have significant positive effects on maintaining cognitive function.

Exercise and Short-Term Cognition

Short bursts of physical activity can also have positive effects on short term cognition. Mullane, Buman, Zeigler, Crespo and Gaesser (2016) aimed to compare cognitive performance following short bouts of activity. Seven female and two male overweight (BMI= 29 $\pm$3kg/m^2) subjects (age= 30 $\pm$ SD 15 years) completed a cognitive performance battery (Cogstate) during four testing sessions separated by a seven day wash-out period. The Cogstate battery consist of three tests (detection test, one back test, and set shifting test) that analyze psychomotor function, working memory, attention, and executive function. The four testing conditions consisted of an eight-hour uninterrupted sitting trial, and three eight-hour trials that included periodical bouts of varying durations (10-30 minutes every hour) of standing, walking (1.6 km/hr), or cycling (20W, 20-30 rpm). Heart rate monitors were used to ensure intensity was similar while subjects were walking and sitting. The results showed accuracy for the sitting trial was significantly lower than the standing, walking, and cycling trials. Reaction time while sitting was significantly higher than when cycling and walking and significantly higher while standing when compared to cycling. This study showed that hourly physical activity during the work day can significantly improve reaction time and accuracy, with the greatest benefits seen with bouts of sit-cycling (Mullane et al., 2016)

The amount of time spent on short bursts of activity is also important. Chang et al. (2015) analyzed the dose-response relationship of exercise duration on cognitive function. In this study, 26 males (age range=20-22 years) completed the Stroop test immediately after one reading condition and three separate exercise conditions. For the reading condition, subjects were asked to read for 30 minutes. For the exercise conditions, the subjects were asked to complete 10, 20, and 45 minutes of steady-state exercise on a stationary cycle ergometer (65% maximum heart rate, 65 rpm). The results showed an inverted U-shaped dose-response relationship between the length of exercise and short-term cognition using the Stroop test, with 20 minutes of exercise prior to conducting the test being the optimal duration (Chang et al., 2015). This shows that exercising prior to a cognitive task can be beneficial, but that exercise duration is also an important consideration. If the activity is too short or too long, the benefits are less. Taking periodic 20-minute breaks throughout the work day may increase cognition and productivity in the workplace.

Occasional bouts of exercise throughout the day elicit benefits other than just cognitive function, including increased energy levels. Wennberg et al. (2016) compared the effects of uninterrupted sitting versus occasional light-intensity walking on fatigue and cognition. During this study, 19 overweight/obese (31.5$\pm$ 4.7 kg/m^2) men and women (age=59.7 $\pm$ 8.1 years) sat uninterrupted or walked (3.2 km/h; 0% grade) for three minutes every half hour of sitting on two separate five-hour test sessions. Fatigue levels were self-reported and cognition was analyzed with a face-name association test, the

Erikson Flanker task, the Stroop test, the n-back test, and a letter memory test. Base-line fatigue levels rose in the uninterrupted sitting phase and fell in the walking phase. Fatigue levels were significantly higher with uninterrupted sitting two hours into testing, and remained so until the end of the trial. Interrupting the work day with light-intensity walking decreased fatigue levels attributed to sitting for long periods of time. While fatigue levels were improved, cognition levels only showed a non-significant positive trend (Wennberg et al., 2016). Although taking walking breaks during the work day may increase energy levels, taking breaks every 30 minutes during the workday may be impractical. Using work-desk treadmills is an option to increase physical activity during the work day without losing work time.

Dual-Task and Cognition

Light-intensity walking while working at a computer can increase energy expenditure during the work day. The question is, will multitasking while working diminish productivity? Bantoft et al. (2016) compared cognitive function at different workstations in 45 undergraduate students (32 female, 13 male; mean age=22.7 years) who completed a battery of cognitive tests on three separate testing sessions, separated by a seven-day wash out period. Two screening tests to assess anxiety and reading ability were completed before testing on the first session. At all three sessions, seven cognitive tests were completed while sitting, standing at a sit-stand workstation, or walking at a self-selected speed (1-3 mph) at a treadmill work station. The cognitive tests included the Digit Span Forward, Digit Span Backward, Digit Symbol Coding, Letter Number Sequencing, Paced Auditory Serial Addition Test, Choice Reaction Time, and Stroop test. The order in which subjects completed the separate testing trials was randomized to avoid the effect of fatigue on test results. The results showed no difference between short-term or working memory, selective or sustained attention, or information processing speed by testing condition (Bantoft et al., 2016). This study showed that cognitive function was not altered during walking while working at a computer in college-aged individuals.

In a similar study, Olinger (2009) conducted a study to analyze cognitive function while sitting, standing and walking. Fifty participants (mean age=43.2 ± 9.3 years) were tested in one 75 minute session where they were asked to complete the Auditory Consonant Trigram Test (ACTT), Golden Stroop Color Word Test (SCWT) and Digital Finger Tapping Test (DFTT) while sitting, standing, and walking (1.6 km/hr) in a randomized order. The results showed no significant change in ACTT or SCWT scores across test conditions. However, there was a small (~2%) yet significant decrease in DFTT scores while walking when compared to sitting and standing. This study showed that while cognition was not necessarily affected by adding a motor skill, dexterity was slightly but negatively affected (Ohlinger, 2009).

Alderman, Olson and Mattina (2014) also compared cognitive function during seated and walking conditions. 66 subjects (27 males, 39 females; mean age=21 ±1.6 years) completed the Stroop test, as well as the Flanker task and a reading comprehension test, while seated and while walking at a self-selected speed on two separate test sessions. The results showed neither response speed nor accuracy were significantly different between conditions (Aldrson et al., 2014).

In a similar study, Sosnowski (2016) compared cognitive function in 15 males and 15 females (mean age=22.7 ± 2.1 years) who completed the Stroop test while sitting, standing, and walking at a self-selected speed at three separate test sessions. The results showed significantly faster reaction times for congruent color-word pairs, and a significantly higher accuracy for both color-word pairs when walking compared to sitting; however, there were no significant differences when comparing sitting to standing. For incongruent color-word pairs, the improvement in reaction time from sitting to walking was insignificant (Sosnowski, 2016). These results are contradicting to Alderman (2014) who showed no difference in young adults. Compared to Ohlinger (2009), the subjects of this study were younger and their results showed a slight improvement in reaction time and accuracy on the Stroop test while walking, while Ohlinger (2009) showed no change in middle aged subjects.

All of these studies show that walking while working did not decrease cognitive function; however, contradictory results have been shown in young adults when using alternative assessments from the Stroop test, such as the Rey Auditory Verbal Learning Test (RAVLT), and the Paced Auditory Serial Attention Test (PASAT) as shown in a study conducted by Larson in 2015.

Larson et al. (2015) compared cognitive function and typing ability during walking and sitting conditions. To measure cognition, the RAVLT and a modified version of the PASAT were used. 75 subjects were randomly assigned into a sitting or walking group. The sitting group (n=38; 17 females, 21 males; mean age=20.7±2.1 years) and walking group (n=37; 23 females, 24 males; mean age=20.84±2.37 years; 1.5 mph) were tested separately. The results showed a small but significant decrease in cognition in the walking group; the walking group also showed significantly worse typing performance (Larson et al., 2015). These contradictory findings could be due to a number of reasons. This was a cross-sectional study while the previously reviewed studies using the Stroop test were crossover designs; this study used a pre-selected speed of 1.5 mph in the walking group; the Stroop test analyzes attention and executive function, whereas the RAVLT analyzes working memory.

Dual-Task and Aging

Cognitive function naturally decreases as individuals age which makes completing single cognitive and motor tasks more difficult, especially when completing them simultaneously. There have been mixed results when analyzing dual-task cost in different age groups. West and Alain (2000) analyzed the effect of age on cognitive function using the Stroop test in 12 younger adults (6 females, 6 males; mean age=27.1 years) and 12 older adults (6 females, 6 males; mean age=69.5 years). As expected, the results showed significantly slower response times in the older adults. When controlling for age-related delay in control trials, there were still significantly slower response times for incongruent trials of the Stroop test in older adults. This suggests that there are declines in cognitive function other than simply reaction time. Older subjects also had a higher percentage of correct answers, perhaps taking their time to answer correctly, sacrificing reaction time (West and Alain, 2000). It is possible that older individuals sacrifice speed to increase accuracy, whereas younger individuals sacrifice accuracy for speed.

In 2004, West conducted a similar study on the effect of age on cognitive performance using the Stroop test by comparing different cueing conditions; trial-by-trial cueing or blocked cueing. During trial-by-trial cueing, the subject is told whether to answer what word is being shown or answer what color the word is printed, as each word appears. During block cueing, subjects are given the same instructions before a large block of color-word pairs appear. In this study, 14 younger adults (6 females, 8 males; mean age=21.4 years) and 14 older adults (10 females, 4 males; mean age=72.2 years) completed the Stroop test under trial-by-trial cueing and blocked cueing while Event-Related Brain Potentials (ERP) were analyzed from an Electroencephalography (EEG), sewn into an electro-cap or adhered to the skin, and eye movement was recorded and analyzed. Reaction time for incongruent color-word pairs was significantly higher for both groups during the trial-by-trial condition. The results also showed that reaction time and accuracy were significantly greater in older adults for both conditions (West, 2006). These studies showed that as individuals age, reaction time on the Stroop test is significantly increased at the expense of accuracy.

Wollesen, Voelcker-Rehage, Regenbrecht and Mattes (2016) analyzed the effect of multitasking on standing and walking performance using the visual-verbal Stroop test in older adults. During this study, 28 subjects, aged 65 to 79 years (10 males, 18 females; mean age=71.3 ±3.6 years), performed the Stroop test, verbally giving their answers rather than on a computer, while sitting, standing, and walking. Subjects also stood still then walked without taking the Stroop test while sway length and velocity were analyzed as a control condition. Sway length and velocity significantly increased while standing still as subjects completed the Stroop test. Step width and length, as well as gait line for the left foot, decreased while walking as subjects completed the Stroop test which showed decreased motor skill. In addition, sitting to walking also resulted in a significantly decreased percentage of correct answers on the Stroop test, which showed a decrease in cognitive function. This study showed that when performing a cognitive and motor task simultaneously, one or the other function will decrease in proficiency for older individuals.

Memorization is also affected by multitasking. Lindenberger, Marsiske, and Baltes (2000) studied the effects of age on completing a motor task simultaneously with a memory task. In this study, 47 young adults, ages 20 to 30 years (mean age=24 years), 45 middle-aged adults, ages 40 to 50 years (mean age=45 years), and 48 older adults, ages 60 to 70 years (mean age=65 years) were required to memorize a list of 16 nouns while walking at a self-selected speed, through either a simple or complex track. The simple track was a traditional oval shaped track while the complex track was designed by a monohedral aperiodle tiling of an isosceles triangle consisting of 22 turning points of varying angles and 21 straight sections of varying length. Accuracy of recalling the memorized list and walking speed were analyzed. Subjects above 40 years old showed greater reductions in memory accuracy while walking, and decreased walking speed while listing memorized nouns; at 60 years there was also an increase in number of missteps while listing nouns (Lindenberger et al., 2000). These studies show that as individuals age, motor and cognitive processes slow, especially when trying to complete two tasks at the same time.

A 2003 metaanalysis questioned whether a decline in function during dual-tasks is equal to or in excess to the decline in function related to general aging. It was concluded that irrespective of age, reaction time increases when completing two tasks simultaneously compared to performing a single task; however, the dual-task cost is higher in older adults and greater than expected when considering general aging (Verhaeghen, Steitz, Sliwinski and Cerella, 2003). While multitasking proved to be more difficult with age, there was no significant effect of between age and accuracy during the cognitive tasks. This supports previous studies that either only reaction time is slowed with age, or perhaps that older individuals sacrifice reaction time to increase accuracy.

CHAPTER III

METHODS

Research Design

This study used a causal-comparative research design to assess the effect of age on cognition while sitting versus walking on a treadmill work station. In this study, the independent variables were age and the testing conditions (sitting and walking). The dependent variables were reaction time, cognitive execution and decision making (% of correct answers) based on congruent and incongruent questions of the Stroop test. Using a cross over design, testing order for each subject was randomized. Heart rate and self-selected walking speed were also analyzed.

Subjects

A convenience sample from the greater Cleveland area was obtained using various forms of advertising including word of mouth, flyers (Appendix A), and recruiting at local YMCAs. 50 subjects, aged 20 to 70 years with 10 subjects (5 males, 5 females) in each age category: 20-29, 30-39, 40-49, 50-59, and 60-69 years participated in this study. Potential subjects were excluded if they required a walking aid or felt uncomfortable walking on a treadmill for five minutes, had a history of colorblindness, or had any medical problems preventing them from completing the study.

Procedures

All tests were administered in the Cleveland State University (CSU) Human Performance Laboratory. Prior to the study, each participant signed an informed consent form (Appendix B) approved by the CSU Institutional Review Board (IRB) which explained all study procedures as well as risks involved. All subjects were administered the AHA/ACSM Health Risk screening questionnaire (Appendix C) to assure no medical complications would prevent a subject from completing the study.

Before test trials, a Polar Heart Rate monitor was attached to the subject who completed a practice Stroop test using Inquisit 4 Lab software uploaded on a treadmill workstation computer (Appendix D) while standing. Subjects were given the option to complete a second practice trial, if they had trouble understanding the instructions during the first practice trial. Once subjects felt comfortable with the testing procedures, they were asked to select a comfortable walking speed, one at which they felt their heart rate rise but were still comfortable typing at the computer. A five-minute break commenced before the first testing trial.

Cognitive performance was measured using the Stroop Test to measure processing speed, executive function, selective attention, and the ability to inhibit habitual responses (Panchana, Thompson, Marcopulos & Yoash-Gantz, 2004). Subjects were asked to identify the color ink which congruently or incongruently corresponded with the written color or the color of a rectangle as a control. Participants selected their answers with a desktop keyboard relating to the color of the word on the computer monitor. Subjects needed to select “d” for red, “f” for green, “j” for blue, and “k” for black; these instructions were displayed at the top of the computer screen (Appendix E).

Examples of congruent and incongruent color-word pairs are shown in the appendix (Appendix F). The test measured the number of correct answers and reaction time for 28 congruent color-word pairs, 28 incongruent color-word pairs, and 28 control blocks.

A cross-over was used to test each test condition (sitting vs walking at a self-selected speed, 0% grade) in a randomly assigned order. Between each testing condition, a five-minute rest was given. The length of each test depended on the individual's ability to answer the questions.

Statistical Analysis

Descriptive statistics were be obtained. Inferential statistics (repeated measures ANOVA) were used to evaluate differences due the independent variables (age; mode of testing; and response type) on the dependent variables (reaction times and correct answers). SPSS (version 22) was used for all analyses with 0.05 used as the level of significance.

CHAPTER IV

RESULTS

Demographics

The purpose of this study was to examine to effect of age on cognitive function while sitting and walking. 50 subjects aged 20-69 years were separated into five groups of 10 subjects (5 males, 5 females) based on age group. Subject demographics are shown in Table I.

Table I: Subject demographics by age group

Age Group	Age (years)	BMI (kg/m²)
20-29	23.1 ± 2.8	23.8 ± 4.4
30-39	33.3 ± 3.0	28.9 ± 6.4
40-49	44.3 ± 3.6	28.1 ± 6.2
50-59	54.1 ± 2.8	25.4 ± 4.5
60-69	65.0 ± 2.4	24.2 ± 5.2

Reaction Time

Reaction time is the time it takes a subject to respond to a stimulus. In this study, reaction time represents the time between the color-word pair appearing on the screen and the subject pressing a computer key. Both incorrect and correct answers were scored and reaction times was averaged for all answers.

A repeated measure ANOVA was conducted to analyze the interaction between testing conditions and age for congruent and incongruent color-word pairs. As subjects increased in age, reaction time significantly increased (p=.001). When color-word pairs were congruent, subjects in their 20s and 30s tended to answer more quickly while walking rather than while sitting. Subjects in their 40s, 50s, and 60s tended to perform faster when sitting rather than walking. When color-word pairs were incongruent, all age groups tended to perform better when walking, except for subjects in their 30s who performed about the same while sitting and walking (1,054.25 ms and 1,054.93 ms, respectively). However, these differences were insignificant. Within-subject analysis showed no significant difference between sitting and walking (p=.502) for any age group. There was no significant interaction between age, testing condition (sitting or walking) and response type (congruent or incongruent). Table II shows the results for reaction time while sitting and walking for congruent and incongruent response types. Figure 1 shows the differences in reaction time for sitting and walking for congruent color-word pairs by age. Figure 2 shows the difference in reaction time for sitting and walking for incongruent color-word pairs.

Table II: Reaction time results ($\bar{x}$±SD)

	Reaction Time Congruent (ms)		Reaction Time Incongruent (ms)	
Age Group (years)	Walking	Sitting	Walking	Sitting
20-29	659.38 ± 173.40	700.70 ± 163.05	768.89 ± 244.96	854.10 ± 260.69
30-39	821.15 ± 191.96	831.35 ± 101.96	1054.93 ± 328.05	1054.25 ± 190.14
40-49	911.21 ± 184.69	896.80 ± 118.82	1121.43 ± 328.11	1171.75 ± 273.93
50-59	1023.03 ± 250.39	1014.94 ± 250.85	1349.64 ± 362.62	1366.73 ± 482.49
60-69	1185.80 ±341.58	1135.37 ± 273.35	1401.61 ± 359.87	1462.89 ± 394.46

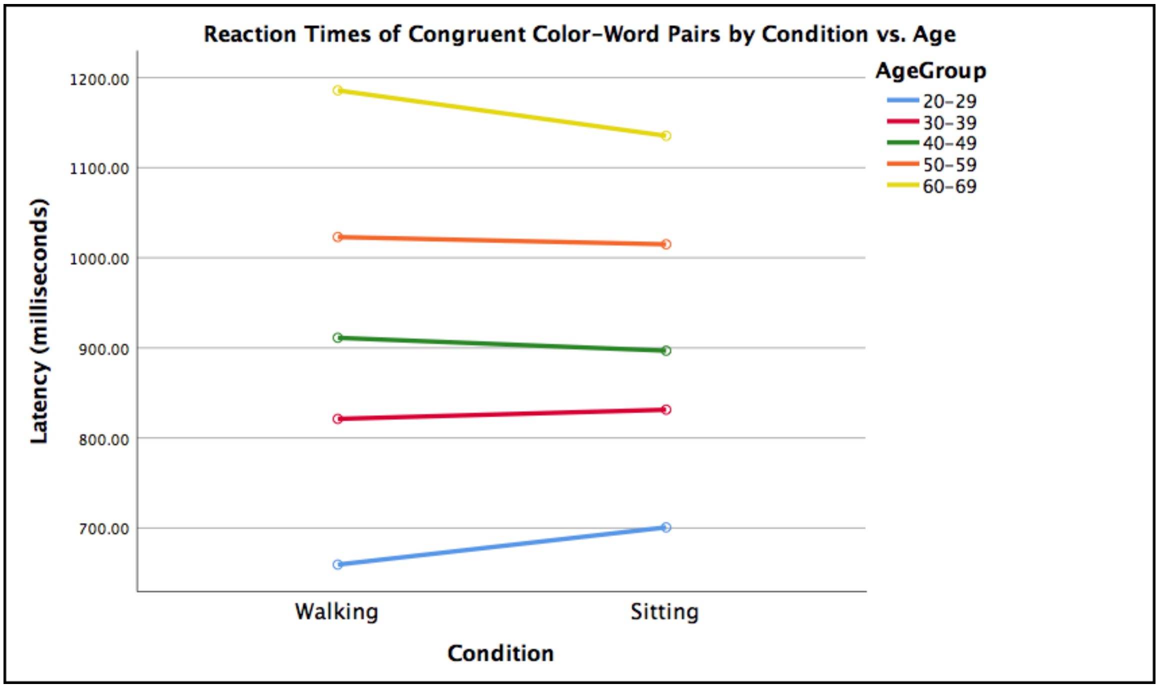

Figure 1: Differences in reaction time for congruent color-word pairs between age groups while sitting and walking

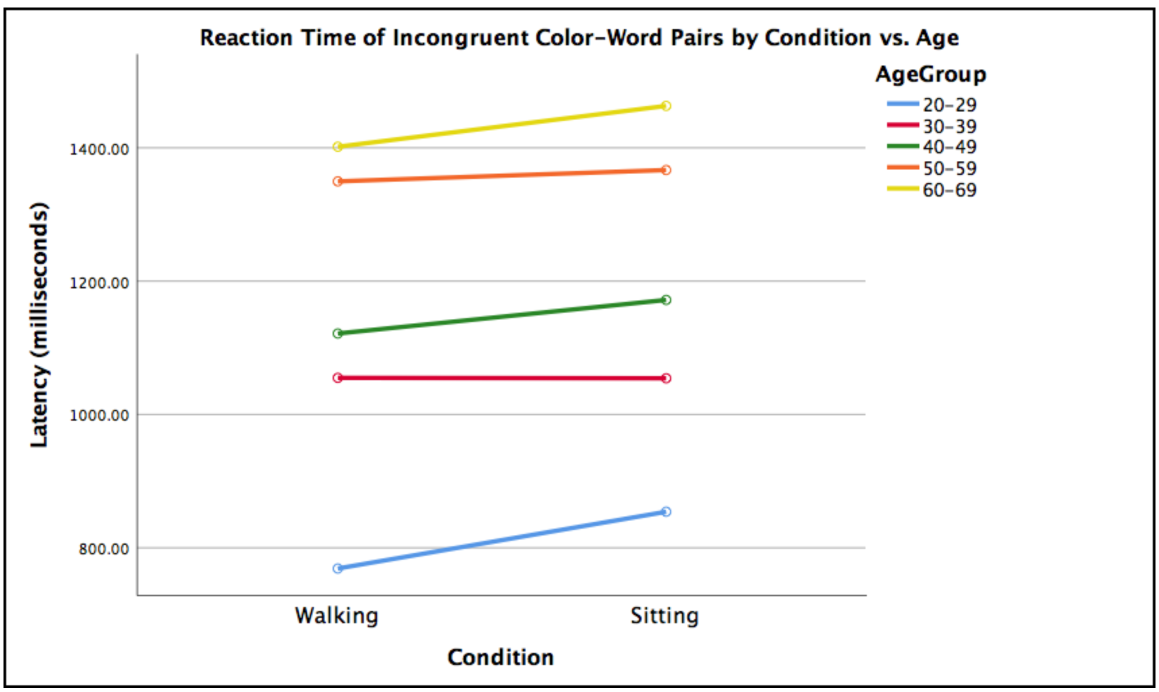

Figure 2: Differences in reaction time for incongruent color-word pairs between age groups

Percent of Correct Answers

Subjects answered correctly on the Stroop test if they pressed the key that correctly corresponded with the color the word was printed in. A repeated measure ANOVA was conducted to analyze the interaction between age, testing condition, and response type for percentage of correct answers. Subjects who were in their 20s, 30s and 40s tended to have more correct answers while walking, while subjects in their 50s and 60s tended to have more correct answers when sitting. These tendencies were insignificant, there was no significant difference between siting and walking, there was no significant difference between age groups, the only significant difference was between response type ($p=.000$). Subjects had more correct answers when responding to congruent color-word pairs than to incongruent color-word pairs. Table III shows the results for percentage of correct answers while sitting and walking for congruent and incongruent color-word pairs. Figure 3 shows the differences in percentage of correct answers for sitting and walking for congruent color-word pairs by age. Figure 4 shows percentage of correct answers for incongruent color-word pairs between age groups.

Table III: Results for percent of correct answers ($\bar{x}$±SD)

	Congruent		Incongruent	
Age Group (years)	Walking	Sitting	Walking	Sitting
20-29	96.6 ± 4.1	96.3 ± 4.3	93.3 ± 7.1	92.9 ±5.6
30-39	99.6 ±1.2	99.2 ± 1.6	94.7 ± 3.2	95.1 ± 4.0
40-49	98.9 ± 2.5	98.5 ± 2.5	93.5 ±13.3	94.8 ± 5.8
50-59	98.5 ± 2.6	98.9 ±1.8	95.2 ± 8.3	96.3 ± 5.4
60-69	98.1 ± 3.6	98.9 ± 2.5	91.5 ± 6.2	93.3 ± 7.5

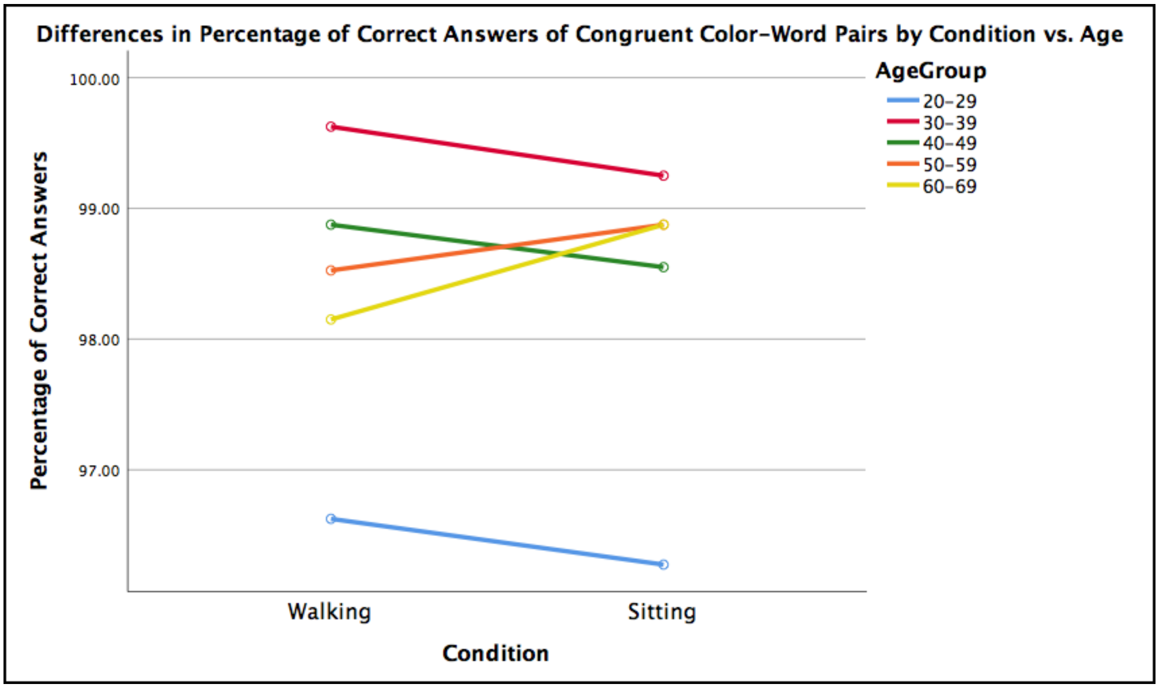

Figure 3: Percent of correct answers for congruent color-word pairs between age groups

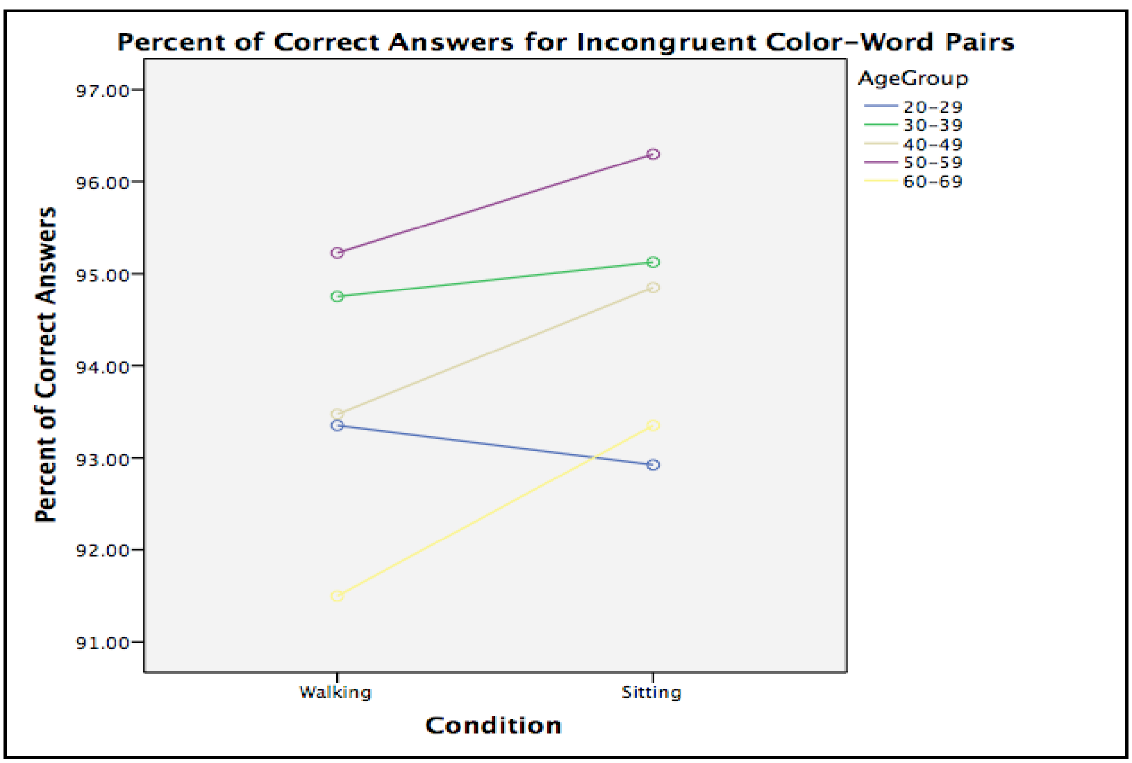

Figure 4: Percent of correct answers for incongruent color-word pairs between age groups

Heart Rate and Walking Speed

Table IV shows the average heart rate change for the different age groups from sitting to walking. Heart rate increased in subjects in their 20s to subjects in their 30s then heart rate decreased with age from subject in their 30s to subjects in their 60s. Table IV also shows the average walking speed selected by each age group. As age increased walking speed insignificantly decreased ($p \geq .05$).

Table IV: Average Heart Rate and Self-Selected Walking Speed While Sitting and Walking by Age Group

	Age Group	Average Heart Rate (bpm) ± SD	Average Walking Speed (mph) ± SD
Sitting	20-29	76.00±14.02	
	30-39	87.30±16.45	
	40-49	81.90±17.12	
	50-59	81.90±20.71	
	60-69	72.60±9.52	
	Total	79.94±16.18	
Walking	20-29	94.40±12.39	2.05±.29 mph
	30-39	108.20±12.48	2.01±.31 mph
	40-49	107.10±11.27	1.92±.53 mph
	50-59	94.10±18.33	1.92±.24 mph
	60-69	91.70±10.35	1.57±.57 mph
	Total	99.10±14.57	1.89±.43 mph

Figure 5 shows heart rates for age groups while sitting and walking. Change in heart rate was significantly higher while walking ($p=.001$), and significantly different amongst age groups ($p=.047$).

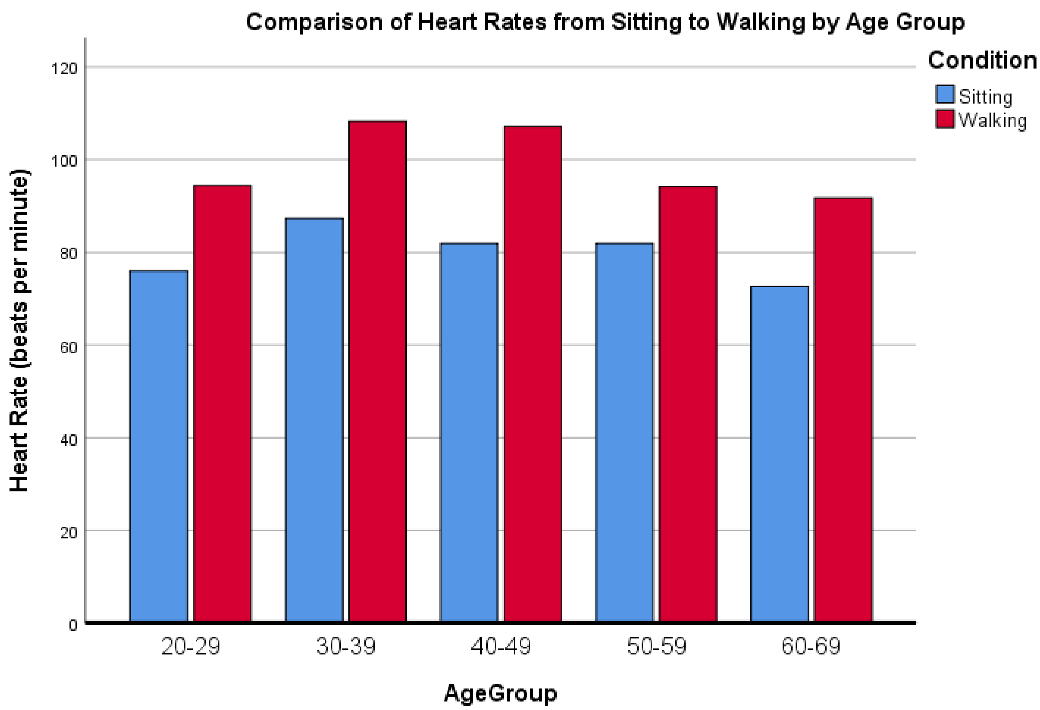

Figure 5: Comparison of Heart Rates from Sitting to Walking by Age Group

Table IV shows the percent increase in HR from sitting to walking and the percent of maximum heart rate (MHR) (220-age) reached while walking.

Table V: Percent of Heart Rate Increase and Percent of MHR by Age Group

Age Group (years)	% increase from sitting to walking	% MHR reached while walking
20-29	24.2%	47.9%
30-39	23.9%	58.0%
40-49	30.8%	61.0%
50-59	14.9%	56.7%
60-69	26.3%	59.2%

CHAPTER V

DISCUSSION

Reaction time is the time it takes for an individual to respond to a stimulus. For this study, reaction time represents the time to press a computer key after seeing a color-word pair on the screen. The results of this study showed a significant increase in reaction time with an increase in age (p=.001). This is to be expected, as there is a general decline in both cognitive and physical function as individuals age. West and Alain (2000) found similar results when comparing the reaction times of young adults (mean age=27.1 years) and older adults (mean age=69.5 years) using the Stroop test. Their study also found a significant increase in reaction time in the older group. West (2006) expanded on his study and found again that older individuals had a longer reaction time when completing the Stroop test when compared to younger individuals. As an individual ages, reaction times generally slow.

Reaction time significantly increased as age increased, but there was no significant interaction between age, testing condition and response type. While reaction time increased with age, the difference between sitting and standing for each age group was similar, small and insignificant, subjects performed slower on incongruent trials than on congruent trials. Completing a simple gait task while simultaneously completing a cognitive task did not affect subjects to a more significant degree as they aged. Verhaeghen et al. (2003) completed a metanalysis on this topic with conflicting findings. This metanalysis found that while young and old age groups experienced an increase in reaction time on cognitive tasks while simultaneously completing a motor task, the increase in reaction time was much larger for older individuals (Verhaeghen etal., 2003). Wollesen et al. (2016) and Lindenberger et al. (2000) also found significantly higher dual-task costs in older individuals as previously outlined in the literature review. The current study contradicts these previous studies with there being no significant difference in increase in reaction time from sitting to walking for older individuals.

When comparing reaction time by testing conditions, whether subjects were sitting or walking, there was no significant difference. Several studies showed similar findings when comparing sitting and walking while completing cognitive tasks. Bantoft et al. (2016) found no significant differences in cognitive scores when sitting, standing, or walking in young adults (mean age=22.7 years). Alderman et al. (2014) conducted a similar study on young adults (mean age=21 years) and also found no significant differences in cognition between sitting and walking. Ohlinger (2009) found similar results in middle aged adults (mean age=43.2 years). However, Ohlinger reported a small (~2%) yet significant ($p<.05$) decrease in dexterity while walking. These studies show that regardless of age, cognition is not affected by the addition of a simple gait task. The findings of this study support this.

The fact that participants did not change in cognitive scores while walking also contrasts past studies. Sosnowski (2016) found faster reaction times when comparing walking to sitting using the Stroop test in young adults (mean age=22.7 years). Younger subjects performed better when walking than while sitting. Opposing results were found by Larson et al. (2015) who used a cross-sectional design on young adults (average age=20.8 years) to compare a sitting group and a walking (1.5 mph) group. Their study showed a decrease in cognition and dexterity when walking. However, the cross-sectional design limits the validity of their findings.

Conflicting and insignificant results may be due to conflicting benefits and hindrances of performing physical activity while simultaneously completing a cognitive task on a computer. Endless studies have shown the benefits of physical activity on cognition (Hillman, Erikson, Kramer, 2008). Ohlinger (2009) and Larson (2015) found significant decreases in dexterity while walking and completing dexterity tests. While physical activity may help activate the brain and decrease reaction time, decreases in dexterity may counter these benefits. Walking at a self-selected speed is a simple task and does not deter from cognitive processes. Dexterity complications are more apparent in older subjects because of losses due to age. The greatest losses in dexterity and upper limb function occur after 65 years and include force steadiness of the hands, hand-arm movement speed, and sense of vibration; this loss is greater than 50% (Carmeli, Patish, and Coleman, 2003). During the present study, it was observed that a small nuber of the older sample had shakiness in the hands that was exasperated while walking. This resulted in incorrect keys being pressed, with corrections needed which resulted in a decrease in reaction time. This could explain why Sosnowski (2016) observed faster reaction times for young subjects who have yet to experience decreases in dexterity.

The testing conditions were administered in a randomized order and subjects were only given one or two practice trials before their first testing trial. Subjects were also asked not to look up or practice the Stroop test prior to coming in to the lab. It was observed that most of the subjects performed better on the second testing trial, regardless of whether they sat or walked in the first testing trial. Davidson, Zacks, and Williams (2003) conducted two experiments to analyze practice-effects by conducting hundreds of Stroop tests in young and old adults. In experiment one, 24 young adults (mean age=20.6 years) and 24 older adults (mean age=73.4years) completed 20 familiarization trials followed by six consecutive blocks of 128 trials. Both groups showed improvement with practice, but the older subjects improved more so than the younger subjects. The greatest improvement was seen from block one to block two, especially for incongruent trials. In experiment two the number of familiarization trials increased to 65 and the subjects (24 young adults, mean age=20.3 years; 24 older adults, mean age=74.9 years) completed 12 blocks of 128 trials on two separate testing days. With the increase in familiarization and practice, the rate of improvement between young subjects and old subjects was similar. For both experiments, the younger subjects had faster reaction times and both age groups improved with practice. However, in experiment one, the rate of improvement was much more significant than in experiment two, where younger and older subjects improved at similar rates (Davidson et al., 2003). This suggests that lack of familiarization and practice in the present study may have affected the results between testing conditions but validates the findings that younger subjects perform faster than older individuals, regardless of practice.

For accuracy, there was a significant difference between congruent and incongruent color-word pairs, but no significant differences between age groups or conditions. All age groups averaged above 96.3% ± 4.3 accuracy for congruent color-word pairs, and above 91.5% ± 6.2 for incongruent color-word pairs. The lowest accuracy was attained by subjects in their 60s with incongruent color-word pairs while walking (91.5%± 6.2). Subjects in their 20s tended to perform better while walking for both congruent and incongruent color-word pairs but this increase in accuracy was very subtle and insignificant. The insignificant difference between conditions was the same across all age groups. Accuracy was generally high, and the differences between ages and conditions were all insignificant. The slight decrease in accuracy with age may be attributed to dexterity issues observed in the older population. There was an observed dexterity decline for older subjects. Some subjects had shaky hands and some subjects were less familiar with the keyboard. This could account for why subjects in the older age group performed less accurately while walking, simply from pressing the wrong key by mistake.

During the walking trial, subjects were asked to select a preferred walking speed. When comparing ages and walking speed, speed insignificantly decreased as age increased. Despite lower walking speeds in older individuals, percentage of maximum heart rate was not lower in older individuals than in younger individuals. A recent article from the American College of Sports Medicine (ACSM, 2016) stated that, when using the 220-age formula to calculate maximum heart rate, beginners should aim to reach 50 to 65 percent of their maximum heart rate for endurance and general aerobic health; intermediate exercisers should aim for 60 to 75 percent, and 70 to 85 percent for consistent aerobic exercisers (ACSM, 2016). Every age group, except subjects in their 20s, was able to reach a heart rate range that would be beneficial for beginners. Depending on how often the subjects exercise, the results of these heart rates have different implications. The ACSM (2014) also stated that healthy individuals should exercise for at least 150 minutes a week at 64 to 76 percent maximum heart rate. No age group reached a minimum of 64 percent of their maximum heart rate. For beginners, walking at a slow pace would elicit health benefits if using a treadmill workstation at work. Regardless of cardiovascular benefits, walking rather than sitting during the work day will increase caloric expenditure, and is therefore beneficial for weight loss.

CHAPTER VI

CONCLUSION

The purpose of this study was to determine if cognitive function was affected by simultaneously completing a motor task, and if that effect increased with age. While older individuals had significantly slower reaction times than younger individuals on the Stroop test, there was no evidence that the increase in reaction time from sitting to walking was greater than that of the younger subjects. While there were trends for faster reaction times in younger individuals, and slower reaction times for older individuals from sitting to walking, these findings were insignificant.

Heart rates were also assessed in this study to determine whether subjects acheived ACSM's guidelines for aerobic training (ACSM, 2014). Heart rates did not reachthe recommended 64-76% MHR. However, moderately increased heart rate would still be beneficial when compared to sitting at a desk for extended periods of time.

Overall, this study showed no significant decline in cognitive function when completing a cognitive task while walking at a treadmill workstation for individuals of any age. Thus, the health benefits of walking while working far outweigh any potential decline of productivity while working.

Application

The use of workstation treadmills can be beneficial in worksites and schools to expend additional calories during traditionally sedentary activities. The finding that younger individuals perform well on cognitive tasks while walking at treadmill workstations could be important to promoting physical activity in schools. Older individuals can also use these devices to increase physical activity at work, which can benefit employee health and reduce employer health care costs.

Limitations

A major limitation was the amount of practice each subject completed before testing trials. If subjects were proficient in the Stroop test before test trials, there may have been more accurate results without a practice-effect. Heart rates were also low due to the short duration of the Stroop test. Completing the test trial after a steady-state heart rate was reached may have more accurately showed how heart rate is while working at a treadmill workstation. This study did not exclude subjects based on exercise rate or BMI. This may also have affected heart rates and self-selected walking speed. Using subjects with equal or similar rates of exercise and BMI would have been a beneficial delimitation to this study.

Future Research

Having subjects of various ages work at a treadmill workstation in a real work environment compared the benefit to those who use a traditional desk could be a more effective way to measure the benefits of a workstation treadmill. To better analyze dual-task costs at different ages, conducting a similar study to this with a larger sample size and higher age groups may be beneficial. Including multiple cognitive tasks, as well as dexterity tasks, may assess cognition more comprehensively. Working at a predetermined heart rate rather than a self-selected walking speed may also be beneficial to this research.

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APPENDIX A

Recruitment Flyer

Cleveland State University

Study Participants Needed

Participants are needed for a study to observe how age affects reaction time and cognition during various workstation settings including sitting and walking at treadmill work stations.

We are looking for volunteers meeting the following criteria:

- 20-80 years of age
- No medical problem
- No history of colorblindness
- Able to walk on a treadmill for five minutes

The study involves one session where upon the subject will complete the Stroop test while both sitting or walking at a treadmill work station. Testing time depends on how long the subject would like to practice and warm up; the test itself lasts less than a minute.

If interested please contact Audrey King at:

audreyking7@live.com

Or Call/Text

(540)845-5464

APPENDIX B

Informed Consent

Cleveland State University

engagedlearning

College of Education and Human Services

Department of Health and Human Performance

Effect of Age on Executive Functioning and Decision Making while Sitting and Walking Informed Consent

This study is being conducted by graduate student Audrey King and supervised by Drs. Kenneth Sparks and Kathleen Little, faculty in the Exercise Science Program at Cleveland State University.

Purpose of Study

I understand that the purpose of this study is to observe the effect of age on cognitive function, measured by the Stroop test, while sitting and walking.

I understand that I will be required to come to Cleveland State University's Human Performance Laboratory one time to complete a series of two Stroop tests while sitting and walking.

Procedures

I understand that I will be asked to perform a cognitive function test (Stroop test) two times during the testing session. I will first be asked to walk on a treadmill while reading a static text on a computer screen to determine a walking speed (4.0 mph maximum) best catered to my gait, and that this speed will be used during the walking condition of the study. I will complete the Stroop test two times, once while sitting and walking, in a random order that will be assigned to me. I will also be required to take a five-minute rest period between each test and to wear three electrodes to monitor my heart rate through the laboratory's telemetry system. I recognize that this one-time session will last approximately one hour with this time period consisting of an explanation of procedures, a Stroop test practice round, the Stroop test during sitting and walking with a five-minute break between each test. The readability of all given text will be between 6th and 8th grade reading levels.

Risks and/or Benefits

I understand the potential risks associated with this study may include mild muscle soreness from walking on the workstation treadmill. I also understand that during the exercise portion of testing, there exists the possibility of certain changes in blood pressure or heart rate, which could possibly result in the occurrence of fainting, heart rhythm disorders, or rare instances of cardiac arrest, stroke, or death (1: 20,000 exercise tests). I understand that the Human Performance Laboratory is equipped with an AED and staff are CPR and First Aid trained. Irritation from the adhesives of the recording electrodes may also occur. I recognize that the Human Performance Laboratory has emergency procedures in place and every effort will be made to minimize these risks. There are no direct benefits to me. The results of this study will help with better understanding the effects of age on cognition while sitting versus walking.

1

Responsibilities of the Participant

I understand that I need to complete a medical history utilizing the American Heart Association/American College of Sports Medicine prescreening questionnaire. This tool is used to determine my risk for experiencing cardiovascular emergencies as a result of exercising. I also understand that I will need to complete the Mini-Mental State examination to rule out any cognitive impairment. The information I submit will be used to determine my eligibility to participate in this study.

Confidentiality

I recognize that any information obtained during the study will be treated as confidential and will not be revealed to any individual without my consent. However, information obtained may be used for research purposes with my right to privacy retained.

The information obtained will be used within Cleveland State University as part of this research. Tests and procedures done solely for this study will be placed in a file secured in the Human Performance laboratory. Any publication of data will only use group data and will not identify me by name.

Freedom of Consent

My participation in this study is entirely voluntary. I know that I am free to stop participation at any time should I choose to do so.

I understand that if I have any questions regarding my rights as a research participant, I am able to contact Cleveland State University's Institutional Review Board (IRB) at 216-687-3630.

Contacts and Questions

The researchers conducting this study are Drs. Kenneth Sparks and Kathleen Little and Ms. Audrey King. I may ask any questions concerning this research study. If I have additional questions at a future time, I am able to reach Dr. Kathleen Little at 216-687-4877 or k.d.little@csuohio.edu, Dr. Kenneth Sparks at 216-687-4831 or k.sparks@csuohio.edu, or Audrey King at (540) 845-5464 or king@horizoncleveland.org.

Participant Acknowledgement

I am 18 years of age or older. The purposes, procedures, known risks and benefits have been explained to me. I have read the consent form, or it has been read to me, and I understand its contents. I have had the opportunity to ask questions and all answers have been relayed to my satisfaction. I voluntarily consent to participate in this study and have been given a copy of the informed consent form.

______________________	______________________	
Signature of Participant	Printed Name	Date
______________________	______________________	
Signature of Witness	Printed Name	Date

2

APPENDX C

AHA/ACSM Pre-participation Screening Questionnaire

Name ________________ Date ____________

AHA/ACSM Pre-participation Screening Questionnaire

Assess Your Health Needs by Marking all ***true*** statements

History

You have had:

- ☐ A heart attack
- ☐ Heart Surgery
- ☐ Cardiac Catheterization
- ☐ Coronary angioplasty (PTCA)
- ☐ Pacemaker/implantable cardiac
- ☐ Defibrillator/rhythm disturbance
- ☐ Heart valve disease
- ☐ Heart failure
- ☐ Heart transplantation
- ☐ Congenital heart disease

Recommendations:

If you marked any of the statements in this section, consult your healthcare provider before engaging in exercise. You may need to use a facility with a medically qualified staff.

Other health issues:

- ☐ You have musculoskeletal problems. *(Specify on back)**
- ☐ You have concerns about the safety of exercise. *(Specify on back)**
- ☐ You take prescription medication (s). *(specify on back)**
- ☐ You are pregnant

Symptoms

- ☐ You experience chest discomfort with exertion.
- ☐ You experience unreasonable breathlessness.
- ☐ You experience dizziness, fainting, blackouts
- ☐ You take heart medications.

Cardiovascular risk factors

- ☐ You are a man older than 45 years.
- ☐ You are a woman older than 55 years or you have had a hysterectomy or you are postmenopausal.
- ☐ You smoke.
- ☐ Your blood pressure is greater than 140/90 mm Hg.
- ☐ You don't know your blood pressure.
- ☐ You take blood pressure medication.
- ☐ You don't know your cholesterol level.
- ☐ You have a blood cholesterol >240 mg/dl.
- ☐ You have a blood relative who had a heart attack before age 55 (*(father/brother)* or 65 *(mother/sister)*.
- ☐ You are diabetic or take medicine to control your blood sugar.
- ☐ You are physically inactive *(i.e., you get less than 30 minutes of physical activity on at least3 days/week)*.
- ☐ You are more than 20 pounds overweight.

If you marked two or more of the statements in this section, you should consult your healthcare provider before engaging in exercise. You might benefit by using a facility with a professionally qualified staff to guide your exercise program.

- ☐ None of the above is true.

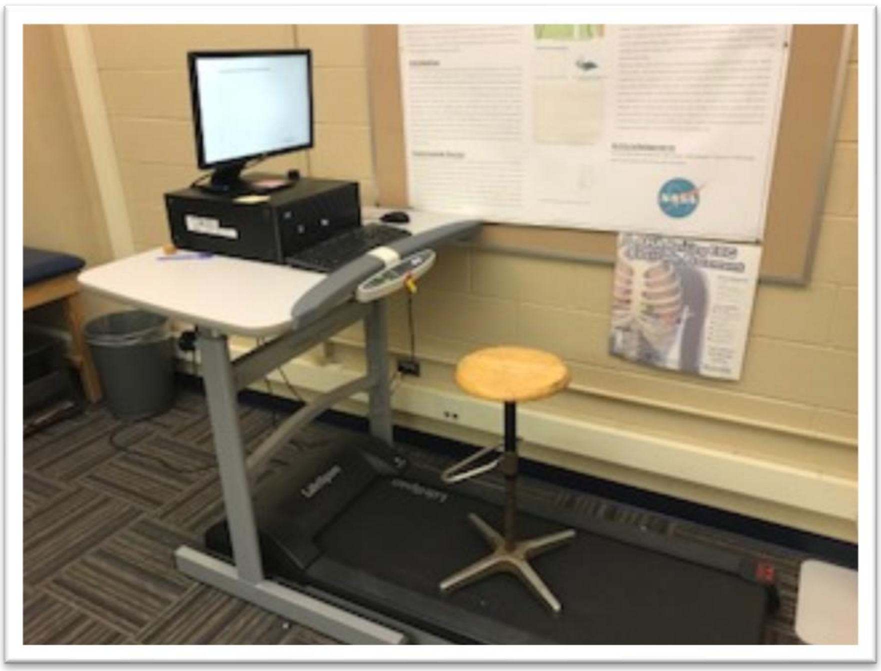
You should be able to exercise safely without consultation of your healthcare provider in almost any facility that meets you needs.

- Proceed with test if musculoskeletal problems are minor, concerns about safety of exercise are normal, and prescription medications are not for cardiac, pulmonary, or metabolic disease.

Risk Status (Low. Moderate, High): ____________

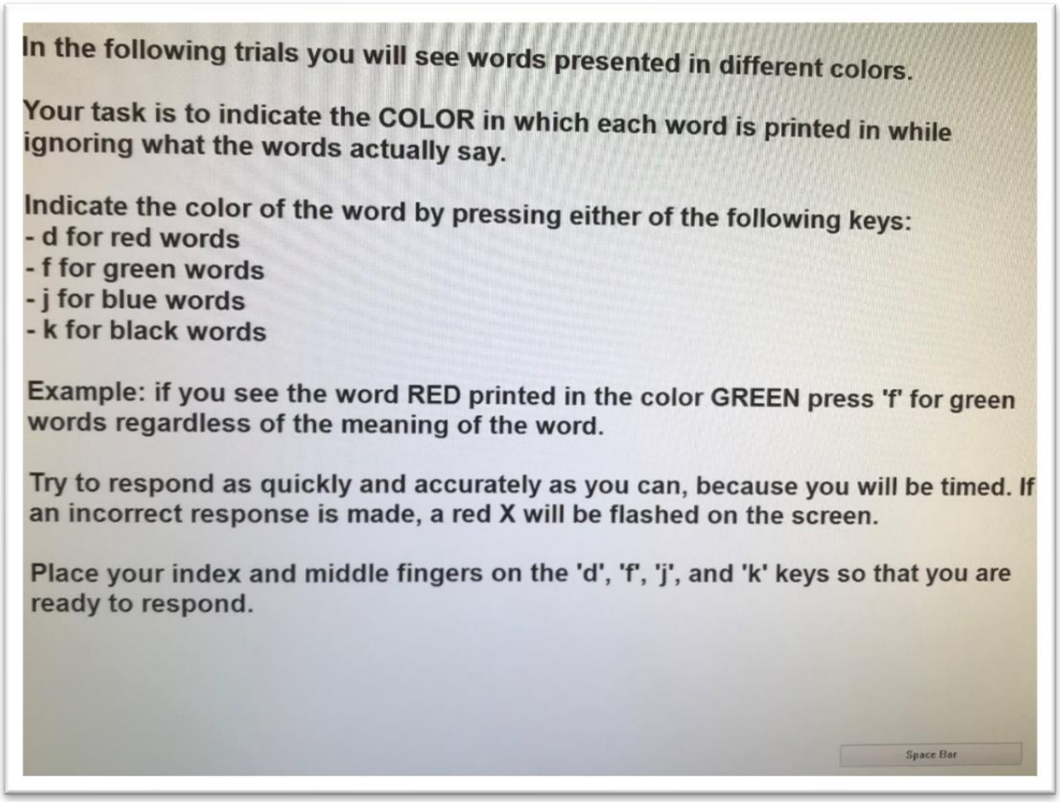
APPENDIX D

TR 1200 DT Workstation Treadmill



APPENDIX E

Subject Instructions



APPENDIX F

Example of Incongruent Color-Word Pair

Example of Congruent Color-Word Pair