Heart Rate as a Physiologic Response to Scenarios on the Driving Simulator

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Introduction: Since driving is such a big part of the American culture and considered an instrumental activity of daily living, it is a critical area for assessment and intervention for occupational therapists. The overall goal of this study was to examine the use of a driving simulator as an occupational therapy assessment and intervention tool. To achieve this, this specific study considered how older adults respond to critical incidents on a driving simulator by comparing their performance with young adults specifically using response time, as measured by heart rate for detection of the incident (perception time) and heart rate recovery time after a critical incident. Methods: Seventy-one participants (33 young, 38 old) completed three scenarios on the STISIM Drive Driving Simulator WT-2000. The scenarios were two familiarization runs and a scenario developed by the researchers, the KANDY Scenario. Baseline heart rate, time to peak heart rate after appearance of each critical incident (response), and time back to baseline heart rate (recovery) were recorded. Results: The data failed to show a difference between older participants and young participants, with one exception, recovery time to critical incident 1 ($t=2.959$, $p=0.006$). Discussion: The recovery time to critical incident 1 was statistically significant due to the fact this was the first opportunity for participants to react quickly. Participants habituated to each subsequent incident, and felt the safety of the driving simulator. Conclusion: These results suggest that efficacy of the driving simulator may be an effective tool for intervention and assessment.

Heart Rate as a Physiologic Response to Scenarios on the Driving Simulator

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Chapter 1: Introduction

Because most people use the car as the main mode of transportation in the United States of America, obtaining a driver's license is a major milestone in one's life (Pellerito, Jr. & Lysack, 2006). With the exception of a few of the largest cities, mobility by personal automobile is the only reasonable method of transportation. The issue becomes when does one give up independence behind the wheel? As the number of drivers over 65 grows (Baker, Falb, Voas, & Lacey, 2003), the concern for driver safety rises.

The normal aging process should be considered when thinking about driver safety. Changes occur in most physiologic systems of the body as we age. Two important examples include vision and cognition. As humans age, physiologic changes occur including the development of glaucoma or cataracts. Even adults, who do not develop these relatively common eye conditions, will see decline in the ability to see clearly (Ball, 1997).

Speed of processing is another natural aging change (Ni, Kang, & Anderson, 2010). This slowing of the cognitive abilities will impact the reaction times of older adults. Older drivers compensate for the slowed reaction time by driving at slower speeds. However, delayed reactions in some instances where speed is not an issue, can lead to crashes, some fatal. For example, unprotected left hand turns require quick processing and reaction after a decision is made (Stutts, & Staplin, 2009). Thus, it is important to examine the reaction time of older adults. It is also important to examine reaction time when slowed cognitive processing is affecting reaction time. Reaction time can be measured through multiple measures. One method of measuring is through physiological observation, using body functions to observe reactions.

In a recent study, driving has been found to be the most valued instrumental activity of daily living for older adults (Dickerson, Reistetter, Schold Davis, & Monohan, 2011). Therefore, as an identified IADL (AOTA, 2008), occupational therapy practitioners, need to address this area of occupation when working with the medically at risk older adults. In addition to established cognition, motor, and visual-perception evaluation tools and interventions, the use of simulation may be an option for therapeutic use in clinical practice. Unfortunately, there is not enough evidence-based research on the use of the simulator either as an assessment or intervention tool. Thus, the purpose of this study is to expand this knowledge by understanding the fundamental interaction between drivers and their responses to use of the simulator. Specifically, the goal is to examine the responses to critical driving incidences, as measured by heart rate recovery time and perception time, to critical events within scenarios on the driving simulator. Examining differences between age groups, will establish a foundation of knowledge about how young and older adults respond to a “crisis” on the simulator and if this physiological knowledge may impact its use as a tool for assessment or intervention.

Chapter 2: Literature Review

Cardiovascular

The cardiovascular system is a three-component system the pump (or heart), the fluid (the blood) and the tubes (blood vessels) (McKinley & O'Loughlin, 2006). The three parts work together with the nervous system to regulate the heart rate (Widmaier, Raff, & Strang, 2006). With influence from the nervous system, heart rate can increase or decrease depending on the stress, or taxation on any of the three parts of the cardiovascular system (McKinley & O'Loughlin, 2006). The viscosity, or thickness, of the blood can change thus altering the heart rate. If the blood vessels have been chronically stressed and plaque has built up, the heart rate can increase. Other physiological stressors can impact all three components of the cardiovascular system altering the heart rate as well as the age of the cardiovascular system (Widmaier, Raff, & Strang, 2006).

Maximum heart rate and age. Physiologically, older and younger adults differ in various ways including maximum heart rate. Previously research has shown that maximum heart rate should be determined using the equation "220-age." The data used to craft the equation 220-age consisted of strict inclusion criteria. Tanaka, Monahan and Seals (2001) examined two studies that developed the equation 220-age. These studies lacked a large number of subjects, and excluded subjects over the age of fifty-five years. Tanaka, et al. (2001) states, "The age-predicted equation was determined 'arbitrarily' from a total of ten studies" (p. 155). This equation shows that physiologically older and younger adults differed in the maximum heart rate, but it was not an accurate depiction of the maximum heart rate.

Tanaka et al. (2001) went on to conduct a meta-analysis to determine a more accurate maximum heart rate equation. By examining numerous studies and including a wider age range to achieve a more accurate equation, Tanaka et al. (2001) found, “Heart Rate Max (HR_{max}) is predicted, to a large extent, by age alone and is independent of gender and physical activity status” (p. 155). The equation for healthy, non-smoking adults was found to be 208 - 0.7 x age (Tanaka et. al, 2001). Thus, the conclusion is that based wholly on age, maximum heart rate is then different for different age cohorts.

Resting heart rate and age. Age does not influence resting heart rate. Braune, Auer, Schulte-Montig, Schwerbrock and Lucking (1996) examined 136 subjects by having subjects lay supine for two minutes to determine a mean resting heart rate. They found there was no difference in resting heart rates between age groups. Any differences exhibited were contributed by the decreased innervation of the Vagus nerve to the sinoatrial (SA) node.

In another study, Overend, Versteegh, Thompson, Birmingham and Vandervoort (2000) compared two groups of adults, one old (75.2 ± 4.6) and one young (23.2 ± 1.7). An ANOVA test demonstrated no difference in resting heart rate values found between the two groups (Overend, Versteegh, Thompson, Birmingham & Vandervoort, 2000). Thus, Braune et al. (1996) and Overend et al. (2000) found no difference with respect to age in resting heart rates.

Target heart rate range. The Karvonen method utilizes resting heart rate and maximum heart rate to determine the target heart rate range (Noble, & Robertson, 1996). Target heart rate range is used in exercise prescriptions to determine the exertion of the exercise for maximum cardiorespiratory benefits. The first step in determining the target heart rate range is to find the difference between the maximum and resting heart rate. The result is the *heart rate reserve*. Since maximum heart rate is determined solely on the age of the client, the resting heart rate makes the target heart rate range more unique to the individual. The *heart rate reserve* is multiplied by 60% and 85%. The result is two low numbers representing the heart rate reserve range. The researcher must add the resting heart rate to the two numbers found to determine the target heart rate range (Noble, & Robertson, 1996).

The Karvonen method is superior to percent of max heart rate method because it utilizes a client's resting heart rate, making it unique to that person. It is important to note the same response in two individuals. For example, a 25 year old has a maximum heart rate of 190.5. Since there are no half beats in the heart, the maximum heart rate is predicted to be 191. The resting heart rate has been found to be 65, and the heart rate reserve is 126. Sixty percent of 126 is 76, and 85% of 126 is 107. The heart rate reserve range is 76 to 107. Addition of the resting heart rate (65) to the heart rate reserve range provides the target heart rate range (141-172 beats per minute). For a 75 year old with the same resting heart rate of 65, has a target heart rate range of 119 to 142 beats per minute. A 25 year old has a target heart rate range of 141-172, and a 75 year old has a target heart rate range of 119-142.

It is important to note that in the above example, both individuals have the same resting heart rate, but different maximum heart rates. If the 25-year-old and the 75-year-old are exposed to a stressful stimulus and both have an increase in heart rate equivalent to 60% of their heart rates, then the heart rate response would appear different. The 25-year-old heart rate increased to 141 beats per minute, and the 75-year-old heart rate increased to 119 beats per minute. It appears the 25-year-old had a greater increase in heart rate than the 75-year-old, however upon closer examination both had a response similar to 60% of the heart rate reserve.

For the present study, to determine if the heart rate response differs in older adults from younger adults on a driving simulation, care must be taken when examining data. Initially the increase in heart rate may appear greater in younger adults, but this is not the case. Younger adults have a greater range from resting heart rate to maximum heart rate than do older adults. The 25-year-old has heart rates from 65 beats per minute to 191 beats per minute. The 75-year-old has heart rates from 65 beats per minute to 156 beats per minute. A stressful stimulus produces a similar response in the young and old adult, but the heart rate (in beats per minute) does not indicate a similar response.

Effects of stress on heart rate. When a person is exposed to a stressful situation heart rate increases. Overend, Versteegh, Thompson, Birmingham, and Vandervoort (2000) conducted a study that examined the effects of heart rate on isokinetic muscular contractions, specifically eccentric and concentric isokinetic contractions. The purpose of the study was to examine if the eccentric isokinetic contraction produced less cardiovascular stress than the concentric isokinetic contraction with regards to age. Overend, et al., (2000) found there was no difference in heart rate responses to concentric and eccentric isokinetic exercises between age groups. One-way ANOVA and two-way ANOVA tests were run with no statistical significance found in terms of age (old v. young), exercise (concentric v. eccentric), and a combination of the two (Overend, Versteegh, Thompson, Birmingham, & Vandervoort, 2000).

The design of the study could be a contributing factor to not finding any statistical significance. The exercises were completed at 50% of the perceived effort for each subject (Overend, et al., 2000). However, perceived exertion is a subjective measure and psychological effects can influence perceived effort. Although the study showed there is no difference in heart rate response to concentric and eccentric isokinetic contraction between age groups, there might have been a difference if effort was measured more objectively.

Jang, Kim, Nam, Wiederhold, Widederhold, and Kim (2002) examined the effects of heart rate increase after the introduction to a stressful stimulus. They examined the heart rate response to a driving simulator and flying simulator, and found a difference in heart rate from baseline measures to the introduction of a virtual environment, the driving simulator. When the subjects (n=11) were exposed to a flying and driving simulator the heart rate increased. However, the heart rate increase was only statistically significant ($\rho<0.005$) when subjects were in the driving simulator. In conclusion, the subjects perceived the driving simulator as a stressful event and thus the heart rate increased from baseline measurements.

Heart rate recovery and age. As individuals age their bodies change physically and physiologically. Accordingly, the physiological response to stress also changes (Eby, Molnar, & Pellerito, Jr., 2006). In fact, men and women experience physical and physiological changes due to the aging process differently (Deschenes, Connell, Jackson, Taylor, & Glass, 2009). Unfortunately, research is limited on psychological and cognitive stress and the heart rate recovery (Shcheslavskaya et al, 2010) and there is conflicting evidence that heart rate recovery declines with age.

Specifically, children have a faster heart rate recovery after maximal exercise effort (Buchheit, Duche, Laursen, & Ratel, 2010). Buchheit et al (2010) studied ten children, six adolescents, and seven adult men. All three groups were asked to perform ten sprints on a stationary bicycle with a significant recovery period. Power output, blood pH and lactate levels were also measured. The results showed that children recovered faster than the adolescents and adults. Buchheit et al (2010) states, "The faster heart rate recovery kinetic observed in children appears to be related, at least in part, to their lower work rate and inherent lack of anaerobic metabolic capacity" (p. 142). Since children are physiologically different than adolescents and adults, these results suggest that heart rate recovery declines as we age.

Dimkpa and Ibhazehiebo (2009) failed to find a relationship between heart rate recovery and age. They compared non-athletic males and after controlling for VO_{2max}, resting heart rate, body mass index, and ratings of perceived exertion and could not find a relationship between heart rate recovery and age. However, the aging process impacts the controlling factors of the study. With increasing age, exercise intensity decreases, contractility of our blood vessels decreases, and VO_{2max} (also known as aerobic capacity) decreases (Dimkpa and Ibhazehiebo, 2009). Although it is very likely aging effects the time it takes to recover from a stressful situation, this was not found by the Dimkpa and Ibhazehiebo (2009) study.

Shcheslavskaya et al. (2010) found that heart rate recovery, when controlling for variables that influence heart rate, was maintained with aging. Five age groups were studied while performing simple math equations and the Stroop Color-Word Task. The heart rate response, and time to recovery to 50%, 75% and 100% heart rate recovery was measured. They failed to find a relationship between heart rate recovery and age. However, the variables controlled for in the study were variables that are influenced by the aging process. Thus, since aging influences a number of physical and physiological factors, it likely affects the heart rate recovery time, but this study failed to find evidence for this.

Driving Simulator

An interactive driving simulator allows an individual to “drive” in any type of environment at no risk to the driver or other drivers on the road. A driving simulator can range from simple components (e.g., brake, accelerator pedal, steering wheel and a computer screen) to elaborate configurations that resemble a real car (Classen, Levy, Meyer, Bewemitz, Lanfor, & Mann, 2011; Mullen, Weaver, Riendeau, Morrison, & Bedard, 2010; Stern & Davis, 2006). Depending on the configurations, driving simulators are used to test specific skills components or the integrative task of driving in a dynamic environment. Although a useful tool, it is not yet established that driving simulators can substitute for on the road evaluations (Harvey, Fraser, Bonner, Warnes, Warrington, Rossor, 1995; Lee, Lee, Cameron, & Li-Tsang, 2003). However, it is likely that occupational therapy practitioners might utilize driving simulators as an intervention tool and/or assessment tool for new drivers, drivers who have attention deficit hyperactivity disorder, older drivers whose skills need to be sharpened (Hunt & Arbesman, 2008) or drivers who need to become more self-aware of their driving abilities (Kay, Bundy, & Clemson, 2009; Stern & Davis, 2006). The driving simulator in the hands of a driving rehabilitation specialist (DRS) may be even more effective as a therapeutic tool, as their specialized skills in driver rehabilitation will enhance their observation and clinical reasoning when an individual responds to a specific incident (Stern & Davis, 2006).

Driving simulator as an intervention tool. As stated above, driving simulators can be used with a variety of clients (Hunt & Arbesman, 2008; Kay, Bundy & Clemson, 2009). Korner-Bitensky, Menon, von Zweck, and Van Benthem (2010) conducted a survey of all occupational therapists in Canada who worked with adults over 55 years of age. This survey found that occupational therapists primarily focus on screening for at risk drivers and fewer conduct assessments, and only 11 of the 133 occupational therapists provide interventions for skills related to driving, refresher courses, or vehicle modifications. Although driving simulators are useful with a wide range of populations, few occupational therapists are using driving simulators as an intervention tool.

Driving simulator as an assessment tool. Occupational therapists, specifically driving rehabilitation specialists (DRS) can utilize driving simulators as an evaluation tool (Stern & Davis, 2006). The STISIM Drive Driving Simulator is a computer software program that allows individuals to experience different environments and scenarios with the capability to be fully customized to fit the assessment, intervention, or screening (2012). Although practice is not quite to the point where driving simulators are being used in place of on-the-road testing, researchers are beginning to explore what would make for a good scenario on the driving simulator. Yuen, Brooks, Azuero, and Burik (2012) surveyed 164 DRS and found four key incidents that should be included in a driving simulator program. Yuen, et al (2012) found “more than 70% of the respondents gave four driving situations a rating of 5 (critically important): turning left across oncoming traffic (86.0%), navigating four-way intersections with traffic lights or signs (77.4%), driving in multiple lanes with traffic on both sides (73.2%), and reacting to unexpected events that require emergency braking or aggressive maneuvers to prevent an accident (71.3%)” (p. 112). Research is headed in the direction of using the driving simulator as an assessment tool.

Crane, Morris, Smith & Strong (2011) showed the physiologic effects, namely heart rate and respiratory rate, of young and middle aged drivers on the driving simulator. The researchers found no difference between the two groups in term of heart rate at the start of the drive as well as the peak heart rate. They also determined there was no difference between the two groups in the amount of time required to return to baseline heart rate (Crane, Morris, Smith, & Strong, 2011). The next question is to examine the difference between young adults and older adults regarding heart rate response to critical incidents on the driving simulator.

Summary

The overall goal of this study is to examine the utility of an interactive driving simulator as an effective and efficient occupational therapy tool for assessment and/or intervention. In order to be valid and reliable, evidence must be available to demonstrate the simulator's effectiveness. As part of that work, physiological response may be useful for determining how it changes in response to stress, particularly in critical incidents of driving. As heart rate is variable as a measure of physiologic response, this study was designed to explore an individual's heart rate in response to critical driving incidents on a driving simulator.

In review of the literature to determine the best method of measuring heart rate, Tanaka et al. (2001) developed an equation to determine maximum heart rate. Older adults and younger adults differ in the maximum heart rate due to age. Resting heart rate can be variable even within age groups, not every 25-year-old has the same resting heart rate. The autonomic innervation of the heart is different for each person, and thus resting heart rate is variable within age cohorts. Additionally, stress can cause different heart rate responses with each person. Thus, heart rate is not a good indicator to determine if there is a difference in the heart rate response between older and younger drivers when exposed to different scenarios on the driving simulator.

On the other hand, response rate may be a more effective indicator of response. The time it takes for heart rate to change is an indication of how quickly one responds and recovers from a stressful stimulus. As we age our aerobic capacity decreases, and the elasticity of our blood vessels decreases. These factors influence how quickly our heart rate recovers and reaches baseline measurements. Although there have been studies that have not showed a relationship between heart rate recovery and age, there are physical and physiological changes that occur in a human body due to aging.

Thus, to achieve the overall goal of this study, heart rate at detection of the incident (perception time) and heart rate recovery time after a critical incident will be measured and performance compared between older adults and young adults. It will be a foundational step to understanding how individuals respond to stress of a critical incident on a simulator and how that information may be beneficial when considering driving simulation in relation or in conjunction with the behind the wheel driving evaluations.

Chapter 3: Methods Section

Design

This study is a quantitative study examining both between and within factors. The specific research questions are: How does a individual's heart rate change by the stress of responding to critical incidents on the driving simulator? Are there age differences in the heart rate response to a critical incident and the recovery to a critical incident on a driving simulator? One of the independent variables is age, with two levels of young and old. The dependent variable is time of reaction, measured in seconds, from the appearance of the critical incident to response as measured by change in heart rate. The second dependent variable will be the time in seconds from the peak heart rate at the time of the critical incident to a baseline heart rate.

Participants

Thirty-three young adults between the ages of 19 and 38 years and 38 older adults over the age of 59 years were tested. Participants were volunteers, recruited using convenience and snowball sampling. Exclusion criteria included anyone with visual impairments, which could not be corrected by eyeglasses and/or non-fluency in the English language for both comprehension and expression. Participants had to be currently licensed to drive and current drivers, specifically driven in the last month. Exclusion criteria included any participant who has acute cardiovascular disease for the fact they were exposed to stressful scenarios on the driving simulator. The demographics information was gathered for each participant including race, age, sex, highest level of education obtained, health rank and any additional health concerns. If the participants were on blood pressure medication the researcher asked if the medication was taken regularly each day. If the participant had not been consistently taking his/her blood pressure medication, they were excluded from the study. Participants were also excluded if they had any health condition or physical disability that may have affected their driving. All participants completed the Simulator Sickness Questionnaire (Kennedy, Lane, Berbaun, & Lilienthal, 1993). Participants were eliminated from the study if they identified themselves as susceptible to motion sickness. Three older participants were eliminated due to simulator sickness and 1 young participant was eliminated (See Table 1).

All participants signed an informed consent prior to the beginning of the study, as approved by East Carolina University's Institutional Review Board (see Appendix A for a copy of the approval form).

Instrumentation

Driving habits questionnaire. The Driving Habits Questionnaire was developed for use with a study that examined older drivers with cataracts and the associated crash risk (Owsley, Stalvey, Wells & Sloane, 1999). The Driving Habits Questionnaire addresses six domains including current driving status, driving exposure, driving space, self-reported crashes and citations, general health and mental status (Owsley, et al., 1999). Variations of the Driving Habits Questionnaire were used in other studies with older drivers (Owsley, et al., 1999).

In the present study, the Driving Habits Questionnaire was utilized to collect demographics about driving from each participant in order to make sure the two groups were similar in driving characteristics and only different in age.

Equipment

The STISIM drive driving simulator WT-2000. The driving simulator is a fixed based simulator with three LCD 21 inch monitors, providing 135^{o} field of view. The driving simulator provides the participant the feeling of being in a car with a mock car interior. The driving simulator resembles a car with a brake and accelerator pedal, steering wheel, two seats and two doors. An image of the driving simulator used for this study can be found in the Appendix E.

System Technology Inc. produces the STISIM Drive, which is the software utilized with the driving simulator (2012). The STISIM software is a computer software program that allows individuals to experience different environments, and scenarios with the capability to be fully customized to fit the assessment, intervention, or screening (2012). The software used for the present study was STISIM Drive Driving Simulator WT-2000. The driving scenarios were conducted on the STISIM Drive Driving Simulator WT-2000. Bedard, Parkkari, Weaver, Riendeau, and Dahlquist (2010) found that the STISIM Drive Driving Simulator is a useful tool to simulate on road scenarios. Bedard, et al., (2010) compared older drivers on the road performance to the Trails A, the Useful Field Of View (UFOV), and a simulated drive using the STISIM Driving Simulator software. "The correlation between the on-road and simulator-based demerit points was .74 (ρ=.035)" (Bedard, Parkkari, Weaver, Ridendeau, and Dahlquist, 2010, p. 338). Although the sample size of older adults was small (n=8), this demonstrated the STISIM is a useful tool to simulate on the road performance.

Power lab 16/30. The heart rate was recorded on the Power Lab 16/30, product number ML870. The software used was the AD Instruments, and the ECG lead wires were MLA0313, with disposable ECG electrodes MLA1010B. Acharya, Kannathal, Hua, and Li (2005) found the PowerLab 16/30 is a useful tool to measure heart rate. All of these items are provided to the researcher by East Carolina University for the sole purpose of conducting research.

KANDY scenario. Three occupational therapy students developed the KANDY Scenario on the STISM DRIVE software with experience on the simulator. It was determined that the scenario should have several key critical incidents. Several critical incidents were developed and a pilot study with four participants was tried. Expert opinion was also sought by a driving rehabilitation specialist, a statistician, and an occupational therapy professor. The KANDY Scenario included a truck backing out quickly into the path of the participant (CI 1: Truck), a stoplight changing directly from green to red (CI 2: Stoplight), a car coming directly at the participant with cement barriers on the right of the participant (CI 3: Head-On), and an adult running out in front of the participant in a neighborhood (CI 4: Pedestrian). The KANDY Scenario also included one stoplight to simulate on-road driving. See Table 2 for a specific description of each specific incident of the KANDY Scenario. The KANDY Scenario was developed solely for this study, so reliability and validity have not been determined. However, the scenario comments were inserted at exactly the same time, or distance, for each participant. See Table 3 for further description of when comments were inserted.

Procedure

A trial study was conducted with four participants to ensure the scenario and heart rate recordings were running as planned. The participants provided feedback on the critical incidents, duration of the testing, environment testing occurred, and additional improvements that could be made. The main purpose of the pilot data was to make sure the heart rate increased at critical incidents and returned to baseline, as well as ensure the critical incidents were such that participants could not avoid the collisions.

Data collection on the 33 young participants occurred between October and December 2011, while the majority of the older participants occurred between January and March 2012. Once screened and the study explained, the participants signed the informed consent. Participants were asked to complete the demographic form, simulator sickness questionnaire, and the Driving Habits Questionnaire.

After completion of demographics, participants were asked to step into the driving simulator and EKG leads are attached to the upper left and right chest as well was the lower left abdomen. We explained how the driving simulator worked. Using two very easy scenarios (called familiarization runs), the participant was asked to “drive” the simulator to become familiar with the software and its equipment. The goal of the familiarization runs is two fold. The first goal is to acclimate the participant to the driving simulator so that the experience would be as close to their normal driving as possible. The second goal is to establish the two average driving heart rates during a drive that was low stress to be used during data analysis. The average heart rate for each of the drives was recorded as data. Descriptions of two familiarization runs are located in Table 4.

A simulator sickness questionnaire was put in place to ensure each of the participants were comfortable throughout the entire data collection process. After the first familiarization run, the researcher asked the participant how they are feeling, and if any nausea is present. If the participant seemed to have any response, rest, water and food were offered. A participant was given about 5 minutes and if they did not want to proceed, that participant was eliminated from the study. If the participant agreed, the second familiarization run was completed. Again, after the second familiarization run was completed, the participant was asked how they were feeling and if they wanted to proceed. The participant then had the opportunity to complete the second familiarization run again, in order to increase comfort with driving in the simulator or continue on to the KANDY Scenario.

During the KANDY Scenario, the heart rate was being recorded on the ADInstruments PowerLab 16/30. The researcher inserted comments, or flags, prior to each of the four critical incidents. The critical incidents occurred at different locations for different participants secondary to the driving speed of the participants. Table 3 provides a further description on the comments and how the KANDY Scenario was the same for each participant. After completion of the KANDY Scenario, the EKG leads were removed, and the study was concluded. If the participant was over 59 years old he/she received a gift card to be thanked for his/her time.

Chapter 4: Results

Demographics

The demographics of the participants can be found in Table 5. The mean age of the young participants was 24.9 (standard deviation (SD)=3.7) years and the mean age older participants was 67.6(6.8) years. There are more females in the younger group (See Table 5), but the difference between the number of females in the older and young groups was not statistically significant (ρ=0.061), although it approached significance.

Using Pearson Chi-Squared the difference between level of education in younger and older drivers was statistically significant (ρ=0.001) with more of the young participants having Bachelor's degrees (See Figure 1). Nineteen young participants and 23 older participants self-reported a health rank of 9/10 or 10/10 or higher (See Figure 2). Thirty-two younger participants were Caucasian and 35 older participants were Caucasian.

Driving Habits and Experiences

Table 6 and 7 illustrates the results of the Driver Habits Questionnaire for both groups. In many of the questions, the participants did not differ, for example: wearing glasses or seatbelts, preferred method to get around, quality of driving, days, places, and total miles driven, etc. One exception was one young participant was not currently driving, but was an experienced driver without a car at the time of the study.

Reports of Driving Difficulty

The majority of all participants reported having no difficulty with driving (See Table 6 & 7). One interesting finding was the total miles driven in a typical week varied between young and older participants (ρ=0.022). Fourteen young participants drove between 0 and 50 miles, and 11 older participants drove between 0 and 50 miles. Only 4 young participants drove 51-100 miles (See Figure 3). Participants reported how fast they drive compared to the general flow of traffic. Four older participants and 12 young participants reported driving somewhat faster, 27 older participants and 19 young participants reported driving about the same as the general flow of traffic (ρ =0.014). In the past three months young participants and older participants differed in the difficulty level when driving on interstates or expressways (See Figure 4). Twenty-eight young participants and 33 older participants had no difficulty at all. Four young participants had little difficulty with interstates or expressways. One young participant and 5 older participants have not driven on interstates or expressways in the past three months (ρ=0.034). In the past year participants reported if they have driven to distant towns. Figure 5 illustrates 33 young participants and 31 older participants reported they had driven to distant towns, 7 older participants did not drive to distant towns (ρ=0.009). Finally, participants reported on the number of accidents and tickets they had received in the past year. Three older participants and 11 young participants reported they had been pulled over by the police (ρ=0.015). Only 1 older participant and 8 young participants received a traffic ticket in the past year (ρ=0.010).

Heart Rate Results

Boxplots were constructed to examine the data and outliers for the older and young participant groups (See Figure 6-17). Outliers were identified as any number below zero, indicating the heart rate was at the highest point at the time the comment was inserted into the heart rate software. Although these outliers were identified as having an increase in heart rate, they were not consistent with the data collection. The comments were inserted at specific points during the KANDY Scenario (as outlined in Table 3), and in order to keep data collection and analysis consistent between participants, the following outliers were eliminated. Outliers include participant 1600 (older male) for reaction to CI 1: Truck, participant 1515 (young female) for reaction to CI 4: Pedestrian. The reaction time for CI 1: Truck for participant 1600 (older male) was eliminated as well as the recovery time for CI 1: Truck due to the recovery time being inaccurate (See Figure 6). The reaction time to CI 4: Pedestrian for participant 1515 (young female) was eliminated as well as the recovery time for CI 4: Pedestrian due to the recovery time being inaccurate (See Figure 9). Both of these outliers had a reaction time that was a negative number. This indicates that the heart rate was at the highest point when the comment was inserted into the ADInstruments system. An additional outlier was identified, participant 1631 (older male) and the recovery time for CI 4: Pedestrian. This data point was eliminated due to the heart rate never returning to normal (see Figure 13) to ensure that the data analysis remained consistent between participants.

After identification of outliers, boxplots for reaction time to CI 1: Truck, reaction time to CI 4: Pedestrian, and recover time to CI 1: Truck and recovery time to CI 4: Pedestrian were again run without the outliers (See Figures 16-17). Then a two-sample t-test was used to analyze the data to compare two group means (time) for reaction time and recovery time without the outliers (see Table 8). There was no statistical significance between older and younger drivers in terms of reaction time or recovery time with one exception, recovery time CI1: Truck ($t=2.959$, $p=0.006$). The difference between older and younger drivers for recovery time CI 3: Head-On was close, but not statistically significant (t=2.008, p=0.053).

The 95% confidence interval was reported for the reaction and recovery times for each critical incident (see Table 8). For each of the reaction and recovery confidence intervals there was a large individual variability. The reaction time to CI 3: Head-On, 95% confidence interval was [-3.36, 2.32], and the recovery time to CI 3: Head-On, 95% confidence interval was [-0.11, 15.33]. The data analysis was such that a comment was inserted at the same point for each participant prior to the critical incident actually occurring (see Table 3).

Chapter 5: Discussion

The study was designed to determine if older and younger adults react differently to critical incidents on the driving simulator and investigate how they react. All participants reacted to the critical incidents on the driving simulator as evidenced by an increase in heart rate upon the appearance of the critical incident. Both older and younger adults also demonstrated a similar ability to recover from the critical incidents as evidenced by a reduction in heart rate after each critical incident. These results answer the first research question that drivers respond physiologically with increased heart rate when a critical incident, or threat, occurs on a driving simulator, and likely on the general roadway.

The study was also designed to investigate if there is an age difference in the reaction and recovery to critical incidents on a driving simulator. Older and younger adults do not demonstrate physiological differences in their reaction time to critical incidents. With one exception, they also did not show any differences in the recovery of their heart rate. These results lend some support that there is not an age difference in the reaction and recovery to critical incidents on the driving simulator, but the fact there was one exception needs to be explained.

In the critical incident that was the exception, it consisted of a truck, visible to the participants, on the side of the road that backs out in the path of the participant. When developing the KANDY scenario, the result the researchers wanted was for participants to avoid critical incident 1. Some participants, both old and young, were unable to avoid the truck. Most participants braked when they saw the truck, although some swerved into oncoming traffic. There was not any consistency with age groups. The difference may be that it was the first critical incident, the first instance on the driving simulator where the participants were forced to react quickly to a stressor. It would appear that with the following three critical incidents, participants habituated to the stressors, meaning participants' reaction and recovery time decreased as the presence of the critical incidents increased. Participants felt the safety of being in a driving simulator and became accustomed to the critical incident appearance and did not react as they may have if placed on the road in an actual car. The first critical incident, the truck, was unexpected and thus could be one reason for the recovery time being statistically significant.

Another reason for the recovery time to critical incident 1, the truck, to be statistically significant is the difference between each participant's cardiovascular system. Aging can affect all three parts of the cardiovascular system. The heart can experience atherosclerosis, which builds up over time. Already the older participants have more time to allow for a build-up of atherosclerosis. The blood and blood vessels can also be different between the two groups. High blood pressure affects the blood and blood vessels. One of the causes of hypertension is older age (Chao, Wu, Chang, & Lin, 2012). An older cardiovascular system could be an additional reason the recovery to CI 1: Truck, was statistically significant.

One interesting demographic that could have impacted the recovery time to CI 1: Truck, was the speed of driving. The older and young participants differed in the education, the number of passengers, difficulty driving on interstates, and distance driven in the past year, however these demographics do not impact the results. The self-reported speed of driving is noteworthy. More young participants reported driving faster than the general flow of traffic than older participants. Classen, Levy, Meyer, Bewemitz, Landford, and Mann (2011) examined the difference between combat veterans and control group; combat veterans drove faster on the driving simulator than the control group and were younger. Also in this study combat veterans engaged in more risky driving than the control group (Classen, Levy, Meyer, Bewemitz, Landford, & Mann, 2011). In the present study, more young participants were reported driving faster than the general flow of traffic, and more reported being pulled over in the past year.

Although the results indicated there was not an age difference between older and younger drivers in the present study, the results should not be extrapolated to describe all older and younger adult drivers. The mean age of the present study older participants was 67.6 (SD=6.8) with only 3 individuals over 80 years old. Adults between 65 and 75 years of age are categorized as young old, and adults over 85 are categorized as oldest old (Suzman, & White Riley, 1985). We know that simulated driving performance decreases with age due to cognitive declines, vision declines and declines in physical ability (Lee, Lee, Cameron, & Li-Tsang, 2003; Brayne, Dufouil, Ahmen, Dening, Chi, McGee, & Huppert, 2000). In order to more fully understand the difference between older and younger drivers, additional research should be conducted examining the old age group (75-85) and the oldest old (85+).

Study Limitations

There were several limitations with this exploratory study. The study participants were a convenience sample rather than a random sample from Eastern North Carolina. This population was predominantly white, healthy, and highly educated. The older adult participants were also young old, with the mean age being 67.61(6.780). The sample size was also small, with only 33 young participants and 38 older participants. A small sample size may sometimes not be representative of the total population. Finally, we provided gas gift cards to our older adult participants due to difficulty of recruiting older adult drivers.

One interesting study limitation was habituation. As the KANDY Scenario progressed, participants became accustomed to the critical incidents. Participants reported they knew they were in a virtual environment, and they were not too worried about the head-on collision, and some were not worried about hitting the pedestrian. Each participant experienced the critical incidents in the same order and thus experienced the same amount of habituation.

Conclusions

The results failed to show a difference in older and young drivers in terms of reaction and recovery time. Perhaps there are better ways to measure reaction time than physiologic response. Even if physiologic response is an adequate method of measuring reaction time, a larger sample might show there is a difference. Although not statistically significant, these findings add to the knowledge base of driver habits and reaction to driving simulators.

Driving is within the scope of occupational therapy practice. The Occupational Therapy Practice Framework defines community mobility as, “moving around in the community and using public or private transportation, such as driving, walking, bicycling, or accessing and riding in buses, taxi cabs, or other transportation systems” (AOTA, 2008, p. 631). In the present study, driving is very important to all of the participants. Forty-eight of the 71 participants stated that they drove 7 days a week, and only 4 people said they drive 3 days a week or fewer. Dickerson, et al (2011) found that driving was the most valued IADL for older adults. In order to stay client centered, occupational therapists should focus on the skills necessary for successful driving and community mobility.

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List of Tables

Table 1.

Simulator Sickness Questionnaire Results

	Older Participants		Young Participants	
Variable	n	%	n	%
General discomfort				
None	35	94.59	31	93.94
Slight	1	2.70	2	6.06
Moderate	1	2.70	1	3.03
Severe	0	0	0	0
Fatigue				
None	32	86.49	26	78.79
Slight	4	10.81	7	21.21
Moderate	1	2.70	0	0
Severe	0	0	0	0
Headache				
None	36	97.30	29	87.88
Slight	1	2.70	3	9.09
Moderate	0	0	1	3.03
Severe	0	0	0	0
Eye strain				
None	35	94.59	29	87.88
Slight	2	5.41	4	12.12
Moderate	0	0	0	0
Severe	0	0	0	0
Difficulty focusing				
None	34	91.89	32	96.97
Slight	2	5.41	1	3.03
Moderate	1	2.70	0	0
Severe	0	0	0	0
Increased salivation				
None	37	100	31	93.94
Slight	0	0	2	6.06
Moderate	0	0	0	0
Severe	0	0	0	0
Sweating				
None	36	97.30	32	96.97
Slight	1	2.70	1	3.03
Moderate	0	0	0	0
Severe	0	0	0	0
Nausea				
None	37	100	32	96.97
Slight	0	0	1	3.03
Moderate	0	0	0	0
Severe	0	0	0	0
Difficulty concentrating				
None	34	91.89	28	84.85
Slight	3	8.11	5	15.15
Moderate	0	0	0	0
Severe	0	0	0	0
“Fullness of the head”				

None	36	97.30	30	90.91
Slight	1	2.70	3	9.09
Moderate	0	0	0	0
Severe	0	0	0	0
Blurred vision				
None	32	86.49	31	93.94
Slight	5	13.51	2	6.06
Moderate	0	0	0	0
Severe	0	0	0	0
Dizzy (eyes open)				
None	37	100	33	100
Slight	0	0	0	0
Moderate	0	0	0	0
Severe	0	0	0	0
Dizzy (eyes closed)				
None	37	100	32	96.97
Slight	0	0	1	3.03
Moderate	0	0	0	0
Severe	0	0	0	0
Vertigo				
None	37	100	33	100
Slight	0	0	0	0
Moderate	0	0	0	0
Severe	0	0	0	0
Stomach awareness				
None	37	100	32	96.97
Slight	0	0	1	3.03
Moderate	0	0	0	0
Severe	0	0	0	0
Burping				
None	36	97.30	31	93.94
Slight	0	0	2	6.06
Moderate	1	2.70	0	0
Severe	0	0	0	0

Table 2.

Description of critical incidents in KANDY Scenario.

Critical Incidents	Description—consistent speed limit of 45 mph
Easy Intersection	When the participant is 5 seconds away the light changes from green to yellow. This incident was not recorded for physiologic reactions
CI 1: Truck	When the participant is 3.5 seconds away the truck pulls out into the path of the participant. There are construction cones just before the truck. This incident was recorded for physiologic reactions.
CI 2: Stoplight	When the participant is 5055 feet from the light, the light changes from green to red. There are trees blocking the cross traffic. There was no avoiding this incident, and physiologic responses were recorded.
CI 3: Head-On	When the participant is 4 seconds away from the truck, he moves into participant's lane. There is a

	construction sign just prior to the collision. There is also a string of vehicles in the oncoming lane, and a cement barricade on the right of the participant. There was no avoiding this incident and physiologic responses were recorded.
CI 4: Pedestrian	When the participant is 65 feet away from pedestrian, he starts to move to walk across the street. There are a string of vehicles in the oncoming lane, and bicyclists on the right of the participant. There was no avoiding this incident and physiologic responses were recorded.

Table 3.

Location of critical incident, in feet, in KANDY Scenario.

Location of critical incidents in Kandy scenario in feet	Action
0	Kandy scenario starts
1600	Location of stoplight (turns green, yellow to red) "Easy Intersection"
2200	Comment (ci1) inserted into PowerLab software
2470	Location of truck backs out in path of participant CI 1: Truck, occurs
4800	Comment (ci2) inserted into PowerLab software
5200	Location of stoplight (turns green to red) CI 2: Stoplight, occurs
Beginning of Cement Wall (feet varies with each participant)	Comment (ci3) inserted into PowerLab software
7815	Location of truck appears 1000 feet away from participant going 50mph CI 3: Head-On, occurs
11900	Comment (ci4) inserted into PowerLab software
12035	Pedestrian walks in path of participant CI 4: Pedestrian
12500	Kandy scenario ends

Table 4.

Description of familiarization runs.

Familiarization Run	Description
Black	Straight, flat, two-lane rural road with no stop signs or stop lights, speed limit between 35 and 55 mph. Five minutes in duration
Brown	Curvy, flat, rural and suburban two-lane road with no turns, and stop signs speed limit between 35 and 55 mph. 5 minutes in duration

Table 5.

Demographics and Health Status Results

Variable	M (SD) Older Participants		M (SD) Young Participants	
Age	67.61 (6.78)		24.88 (3.73)	
Age	8.55 (1.47)		8.55 (0.83)	
Gender	n (old)	% (old)	n (young)	% (young)
Male	16	42.11	7	21.21
Female	22	57.89	26	78.79
Highest Level of Education**				
Grammar School	2	5.26	0	0
High School/GED	2	5.26	0	0
Some college	8	21.05	3	9.09
College Degree	9	23.68	30	90.91
Graduate work or professional level	17	44.74	0	0
Ethnicity				
Asian/Pacific Islander	1	2.63	0	0
Black/African-American	2	5.26	0	0
White/Caucasian	35	92.11	32	96.97
White/Caucasian and Latino	0	0	1	3.03

**Significant at the α=0.05.

Table 6.

Driving Habits Questionnaire Responses from Participants using Pearson's Chi-Squared Test

	Older Participants		Young Participants		
Variable	n	%	n	%	ρ-value
Do you wear a seatbelt when you drive?					1.000
Always	36	94.74	31	93.94	
Sometimes	2	5.26	2	6.06	
Never	0	0	0	0	
Has anyone suggested over the past year that you limit your driving or stop driving?					N/A
Yes	0	0	0	0	
No	38	100	33	100	
How fast do you drive compared to the general flow of traffic?**					.014
Much faster	0	0	1	3.03	
Somewhat faster	4	10.53	12	36.36	
About the same	27	71.05	19	57.58	
Somewhat slower	7	18.42	1	3.03	
Much slower	0	0	0	0	
If you had to go somewhere and didn't					0.754

want to drive yourself what would you do?					
Ask a friend or relative to drive you	29	87.88	29	87.88	
Call a taxi or take the bus	0	0	0	0	
Drive yourself regardless of how you feel	3	9.09	3	9.09	
Cancel or postpone your plans and stay home	1	3.03	1	3.03	
Other	0	0	0	0	
Please tell me all the places you drive in a typical week.					0.272
0 places	0	0	1	3.03	
1-3 places	12	32.43	8	24.24	
4-6 places	16	43.24	18	54.55	
7-9 places	7	18.92	2	6.06	
10+ places	2	5.41	4	12.12	
Total miles driven in a typical week.**					0.022
0-50 miles	11	28.95	14	42.42	
51-100 miles	12	31.58	4	12.12	
101-150 miles	1	2.63	6	18.18	
151-200 miles	6	15.79	1	3.03	
201-250 miles	2	5.26	1	3.03	
251-300 miles	4	10.53	1	3.03	
301-350 miles	1	2.63	1	3.03	
351-400 miles	1	2.63	0	0	
401-450 miles	0	0	0	0	
451-500 miles	0	0	3	9.09	
501-550 miles	0	0	0	0	
551-600 miles	0	0	2	6.06	
When traveling with this individual who usually drives?					0.738
I drive	16	42.11	17	44.74	
About half and half	14	36.84	11	33.33	
This person drives	5	13.16	5	15.15	
Difficulty with driving when it was raining during the past 3 months.					0.385
No difficulty at all	23	62.16	17	51.52	
Little difficulty	11	29.73	14	42.42	
Moderate difficulty	3	8.11	1	3.03	
Extreme difficulty	0	0	0	0	
Did no do	0	0	1	3.03	
Difficulty with parallel parking during the past 3 months.					0.247
No difficulty at all	19	50.00	13	39.39	
Little difficulty	4	10.53	9	27.27	
Moderate difficulty	1	2.63	2	6.06	
Extreme difficulty	0	0	0	0	
Did no do	14	36.84	9	27.27	
Difficulty with making left-hand turns across oncoming traffic during the past 3 months.					0.601
No difficulty at all	32	84.21	30	90.91	
Little difficulty	3	7.89	3	9.09	
Moderate difficulty	1	2.63	0	0	

Extreme difficulty	0	0	0	0	
Did no do	1	2.63	0	0	
Difficulty with driving on high-traffic roads during the past 3 months.					0.724
No difficulty at all	32	84.21	28	84.85	
Little difficulty	3	7.89	2	6.06	
Moderate difficulty	2	5.26	3	9.09	
Extreme difficulty	0	0	0	0	
Did no do	1	2.63	0	0	
Difficulty with driving in rush-hour traffic during the past 3 months.					0.558
No difficulty at all	30	78.95	23	69.70	
Little difficulty	2	5.26	5	15.15	
Moderate difficulty	3	7.89	2	6.06	
Extreme difficulty	0	0	0	0	
Did no do	3	7.89	3	9.09	
Difficulty with driving at night during the past 3 months.					0.538
No difficulty at all	25	65.79	26	78.79	
Little difficulty	8	21.05	5	15.15	
Moderate difficulty	4	19.53	1	3.03	
Extreme difficulty	0	0	0	0	
Did no do	1	2.63	1	3.03	
During the past year, have you driven in your immediate neighborhood?					N/A
Yes	38	100	33	100	
No	0	0	0	0	

**Significant at α=0.05

Table 7.

Driving Habits Questionnaire Responses from Participants, using Fisher's Exact Test

	Older Participants		Young Participants		
Variable	n	%	n	%	ρ-value
Do you wear glasses or contact lenses when you drive					0.212
Yes	27	71.05	19	57.58	
No	10	26.32	14	42.42	
Which way do you prefer to get around?					1.000
Drive self	34	89.47	31	93.94	
Have someone drive you	3	7.89	2	6.06	
Use public transportation or taxi	1	2.63	0	0	
How would you rate the quality of your driving?					0.097
Excellent	12	31.58	6	18.18	
Good	24	35.29	19	57.58	
Average	2	5.26	5	15.15	
Fair	0	0	3	9.09	

Poor	0	0	0	0	
Did no do	0	0	1	3.03	
Difficulty with driving alone during the past 3 months.					0.212
No difficulty at all	38	100	31	93.94	
Little difficulty	0	0	2	6.06	
Difficulty with driving on interstates or expressways during the past 3 months.*					0.034
No difficulty at all	33	86.84	28	84.85	
Little difficulty	0	0	4	12.12	
Did no do	5	13.15	1	3.03	
During the past year, have you driven to neighboring towns?					0.495
Yes	36	94.74	33	100	
No	2	5.26	0	0	
During the past year, have you driven to more distant towns?*					0.013
Yes	31	81.58	33	100	
No	7	18.42	0	0	
During the past year, have you driven to places outside the state?					0.209
Yes	23	60.52	25	75.76	
No	15	39.47	8	24.24	
During the past year, have you driven to places outside the southeast region of the USA?					0.480
Yes	16	42.11	17	51.52	
No	22	57.89	16	48.48	
In an average week how many days per week do you normally drive?					0.802
6 or fewer days/week	13	34.21	10	30.30	
7 days/week	25	65.79	23	69.70	
Total number of friends an/or family members that you regularly travel with in a car over the past year					0.099
0 or 1 person	24	63.16	14	42.42	
2 or more people	14	36.84	19	57.58	
Have you been involved in an accident over the past year where you were the driver?					1.000
Yes	3	7.89	3	9.09	
No	35	92.11	30	90.91	
Have you been in an accident over the past year when you were the driver where the police were called to the scene?					1.000
Yes	3	7.89	3	9.09	
No	35	92.11	30	90.91	
Have you been pulled over by the police, regardless of whether you received a ticket in the past year?*					0.015
Yes	3	7.89	11	33.33	
No	35	92.11	22	66.67	

Have you received a traffic ticket (other than a parking ticket) where you were found to be guilty, regardless of whether or not you think you were at fault in the past year? *					0.010
Yes	1	2.63	8	24.24	
No	37	97.37	25	75.76	

*Significant at α=0.05

Table 8.

Difference in reaction and recovery of older participants and young participants outliers eliminated

Critical Incident	**Older Participants**		**Young Participants**		**t-statistic**	**ρ-value**	**95% CI**	
	M	SD	M	SD			LL	UL
Reaction								
CI 1: Truck	8.26	4.65	10.00	4.47	-1.454	.152	-4.13	0.66
CI 2: Stoplight	10.25	3.83	11.63	3.70	-1.430	.158	-3.31	0.55
CI 3: Head-On	9.53	4.81	10.05	6.24	-0.368	.714	-3.36	2.32
CI 4: Pedestrian	7.79	3.48	9.08	3.95	-1.334	.188	-3.23	0.65
Recovery								
CI 1: Truck	11.48	10.23	4.90	3.54	3.188	.003**	2.37	10.80
CI 2: Stoplight	11.55	11.78	10.73	5.79	0.338	.737	-4.07	5.70
CI 3: Head-On	13.05	19.73	5.45	5.46	2.008	.053	-0.11	15.33
CI 4: Pedestrian	9.90	10.96	8.68	5.52	0.478	.635	-3.61	5.83

**Significant at α=0.05

List of Figures

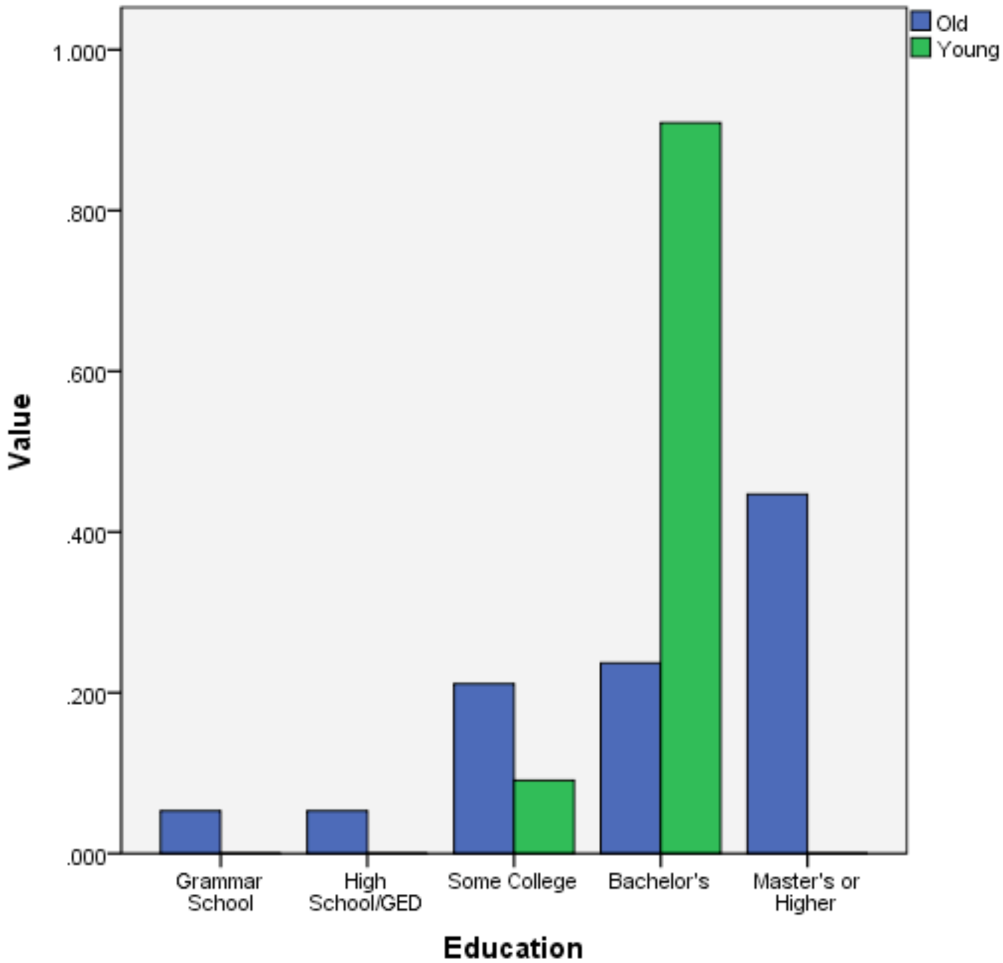

Figure 1. Participants' highest level of education obtained (ρ=0.001).

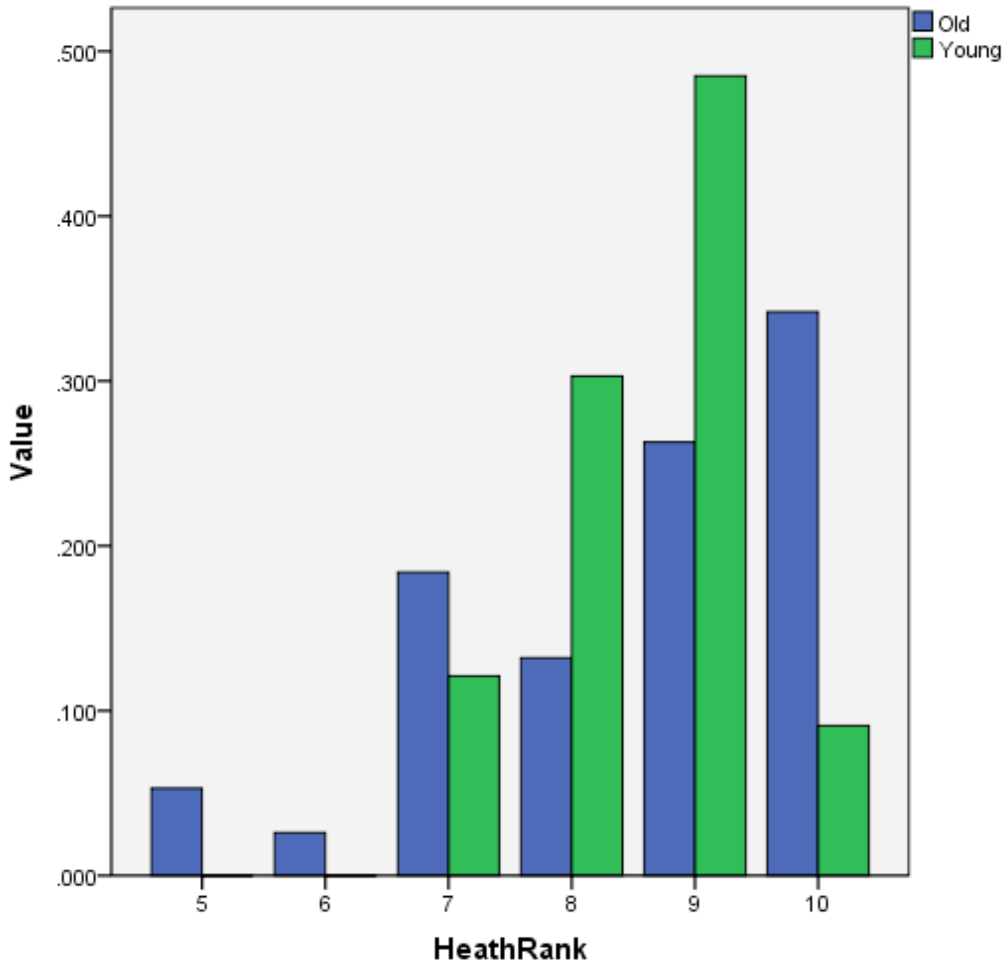

Figure 2. Participants' health rank (ρ=0.250).

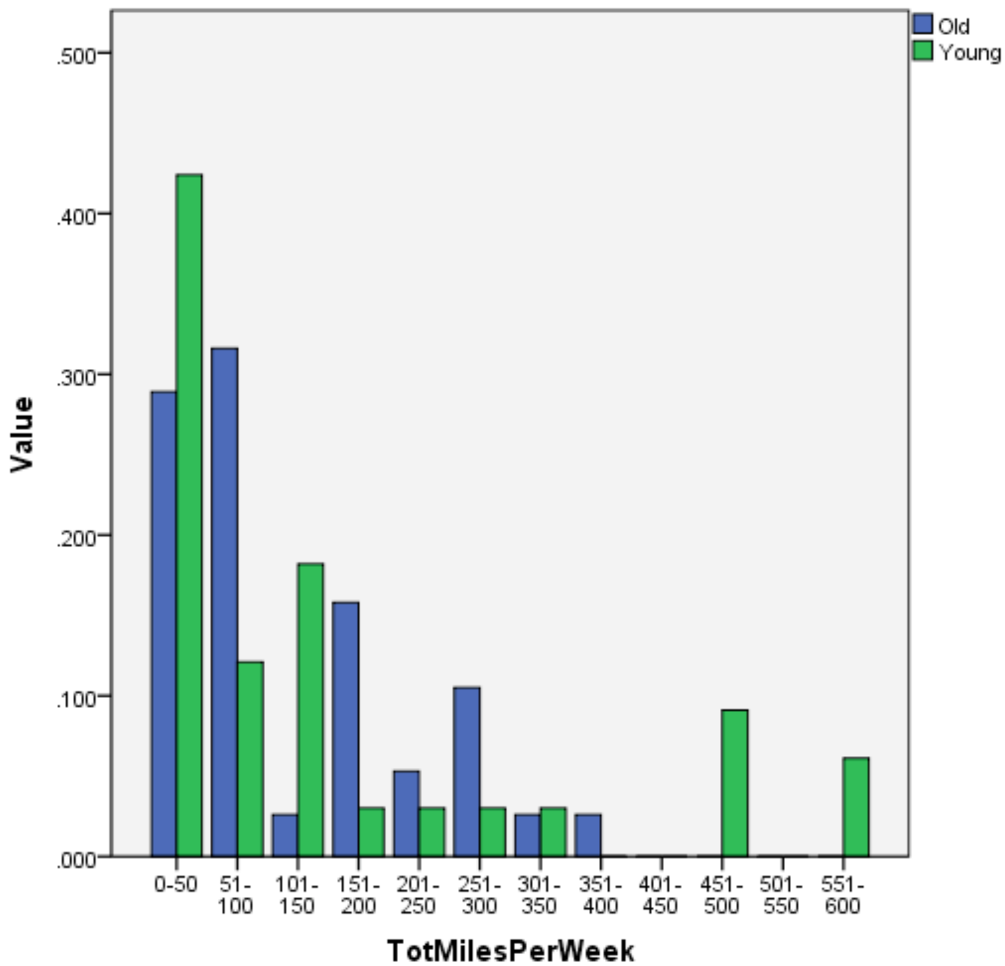

Figure 3. Total miles driven in a typical week (ρ=0.022).

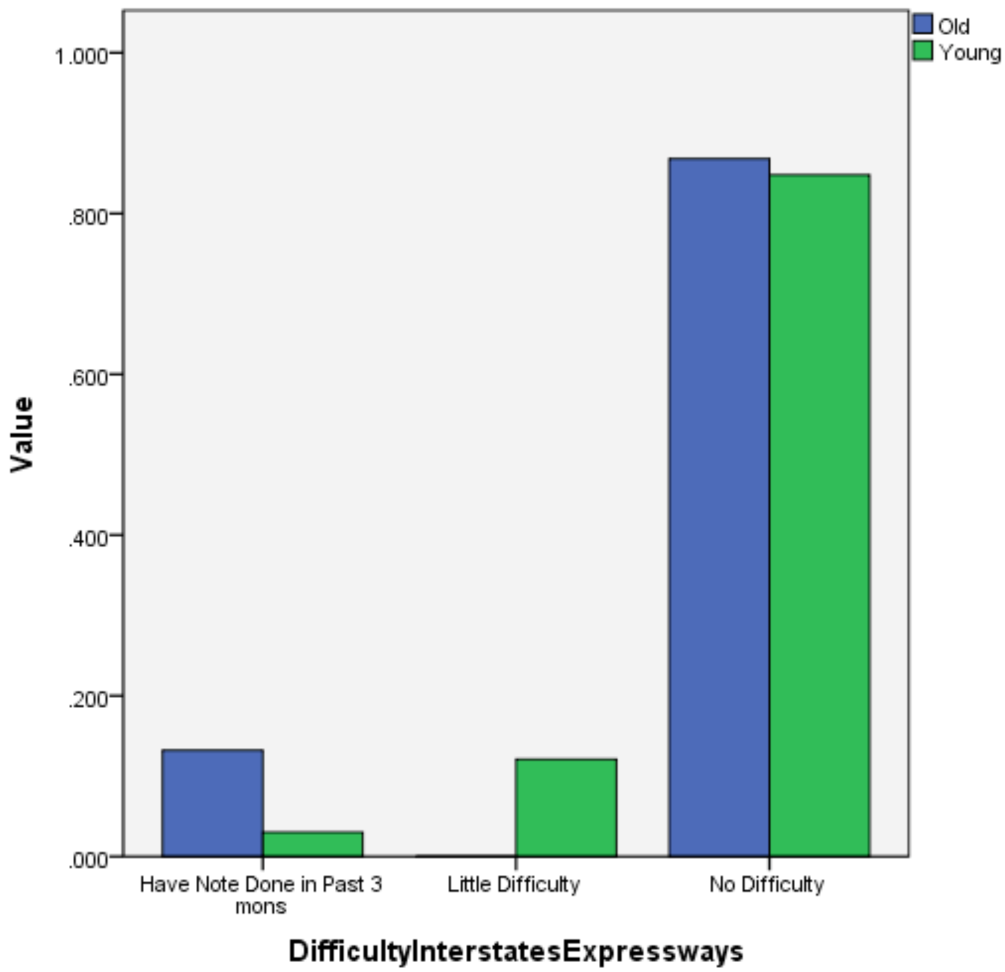

Figure 4 During the past 3 months, have you driven on interstates or expressways? (ρ=0.034).

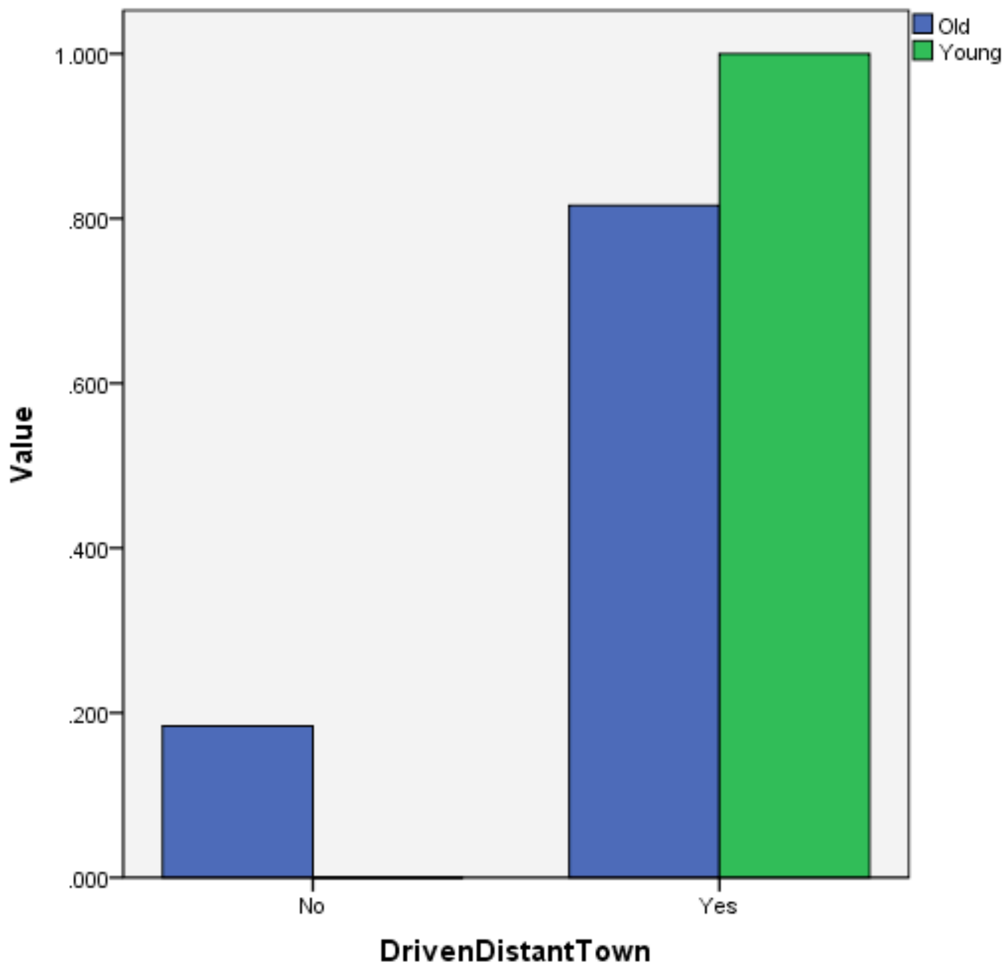

Figure 5. During the past year, have you driven to more distant towns? (ρ=0.009).

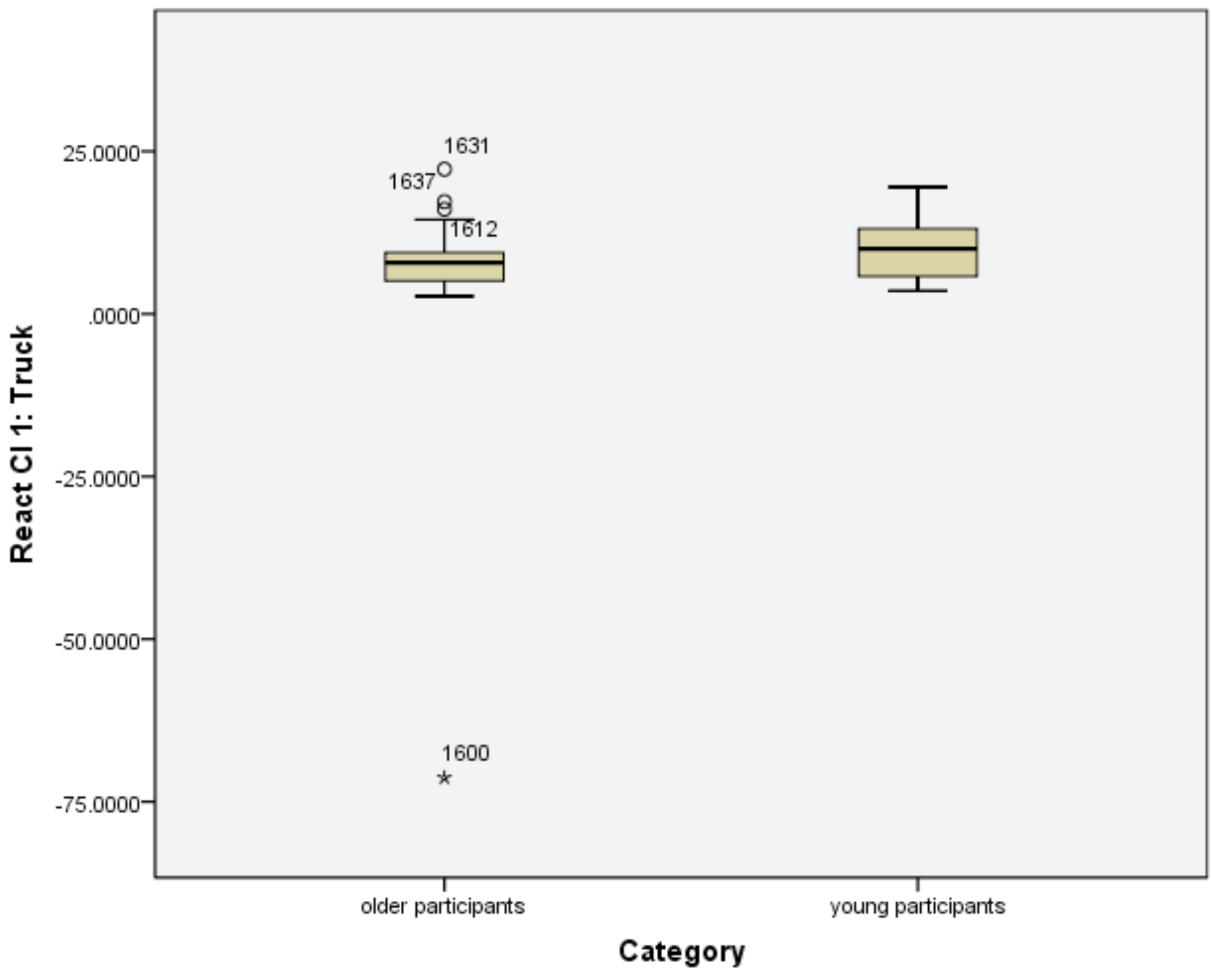

Figure 6. Boxplot for reaction time to CI 1: Truck.

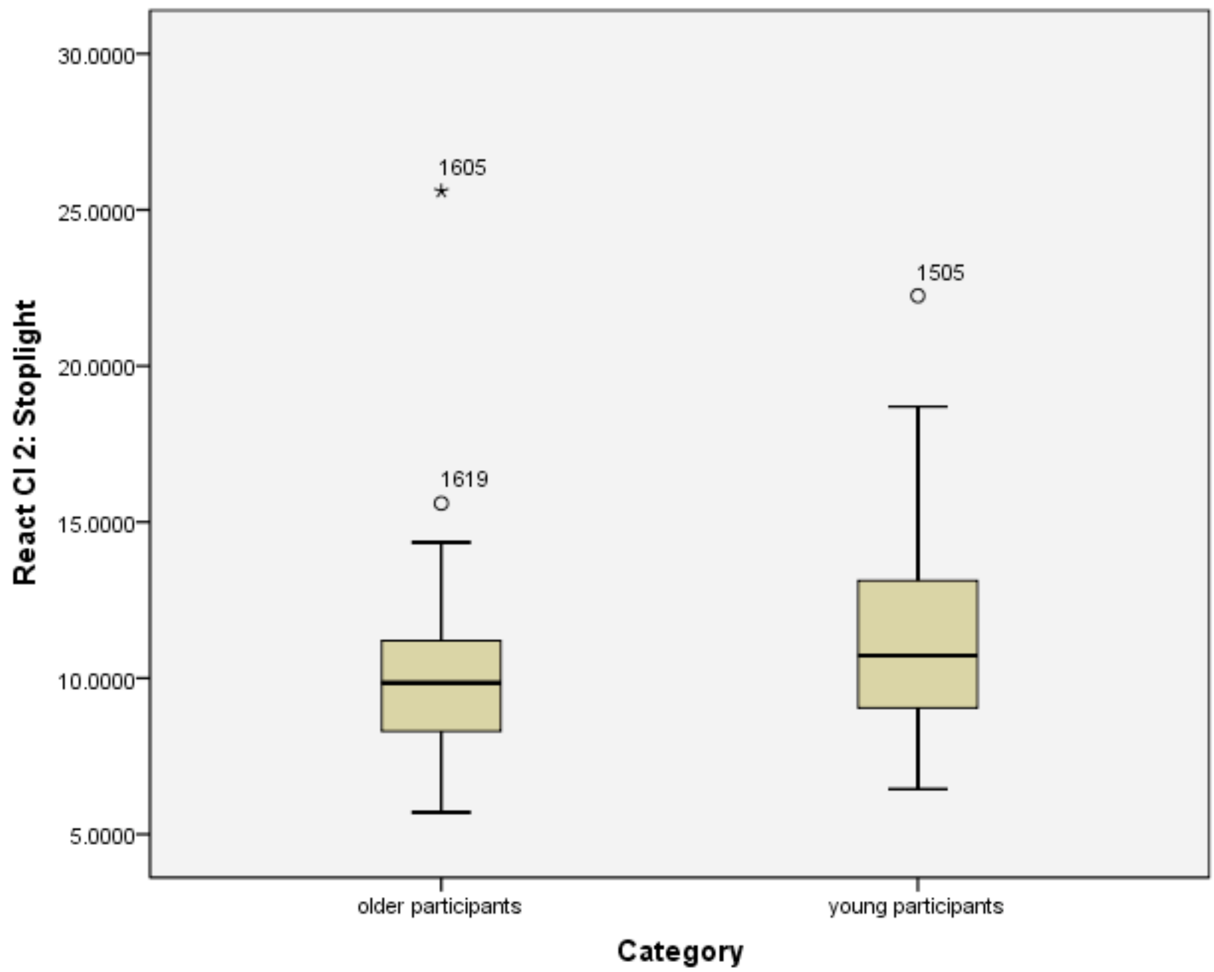

Figure 7. Boxplot for reaction time to CI 2: Stoplight.

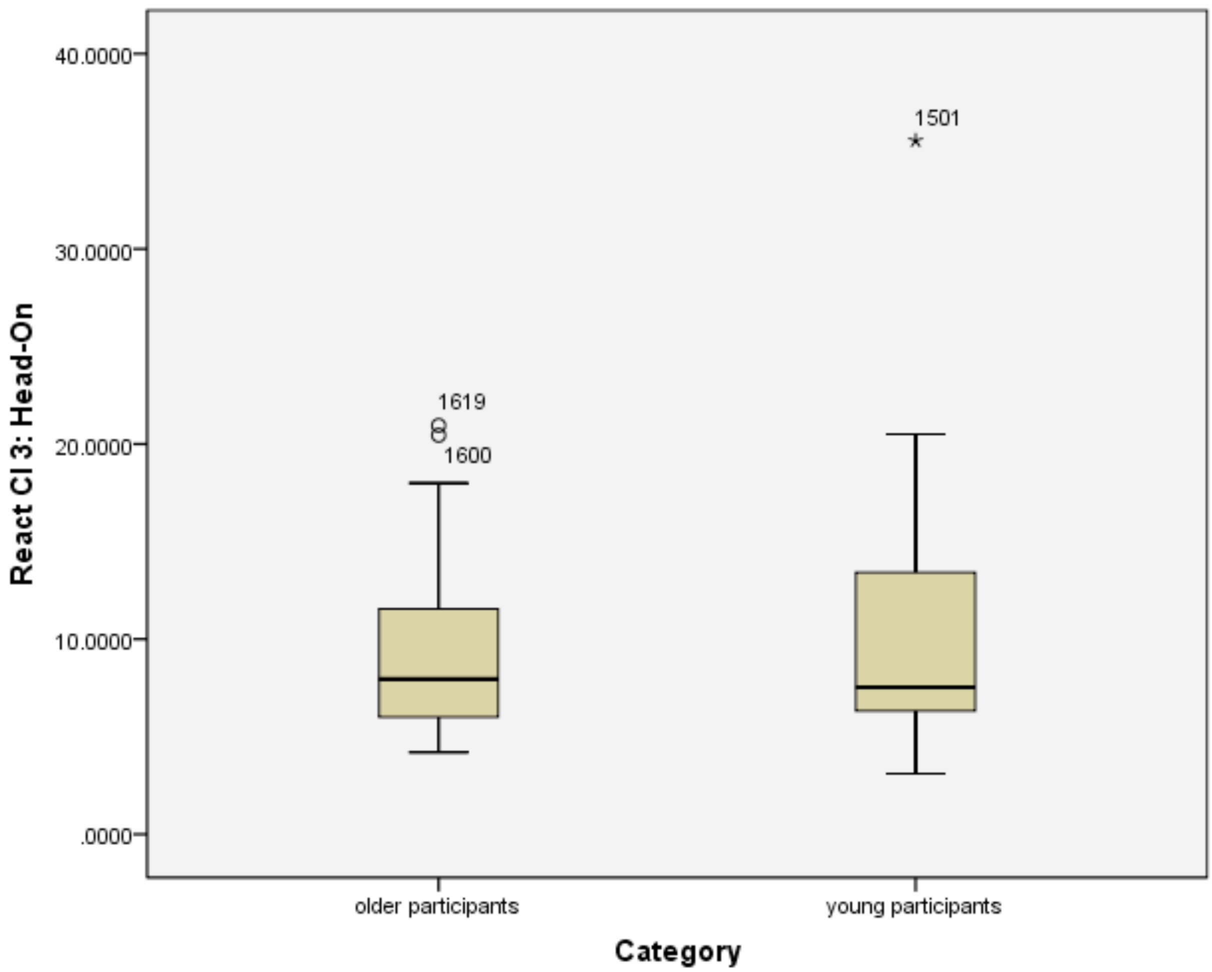

Figure 8. Boxplot for reaction time to CI 3: Head-On.

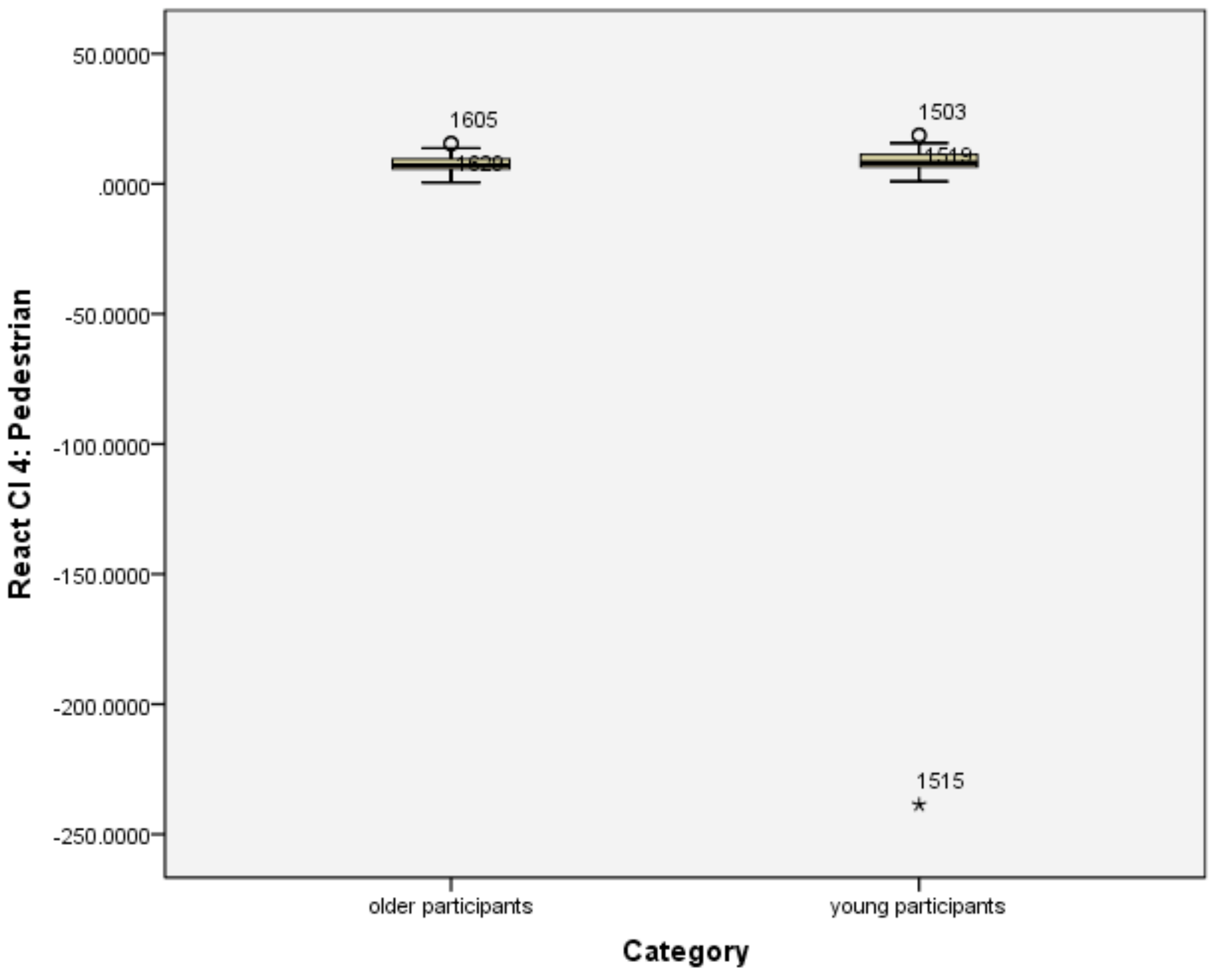

Figure 9. Boxplot for reaction time to CI 4: Pedestrian.

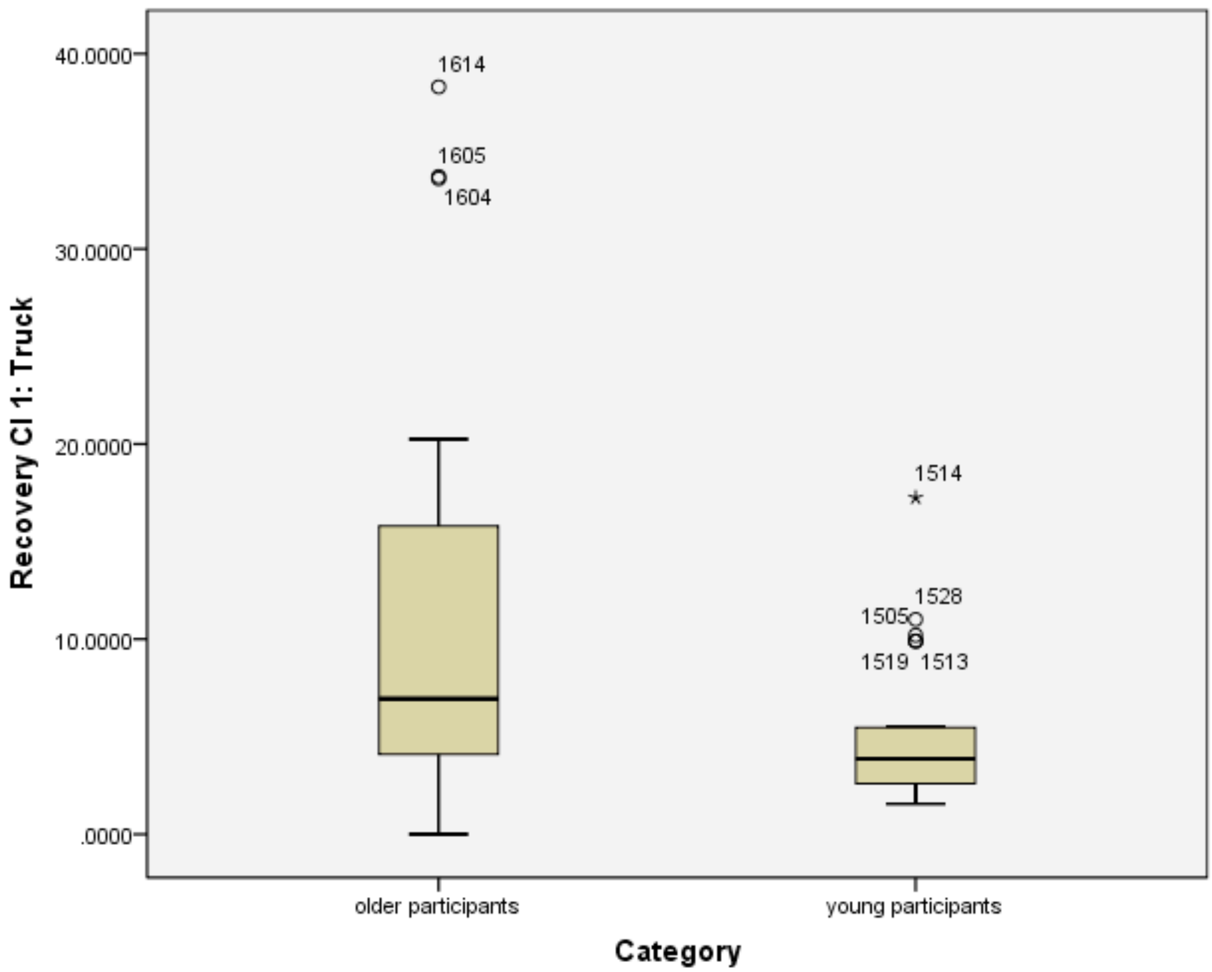

Figure 10. Boxplot for recovery time to CI 1: Truck.

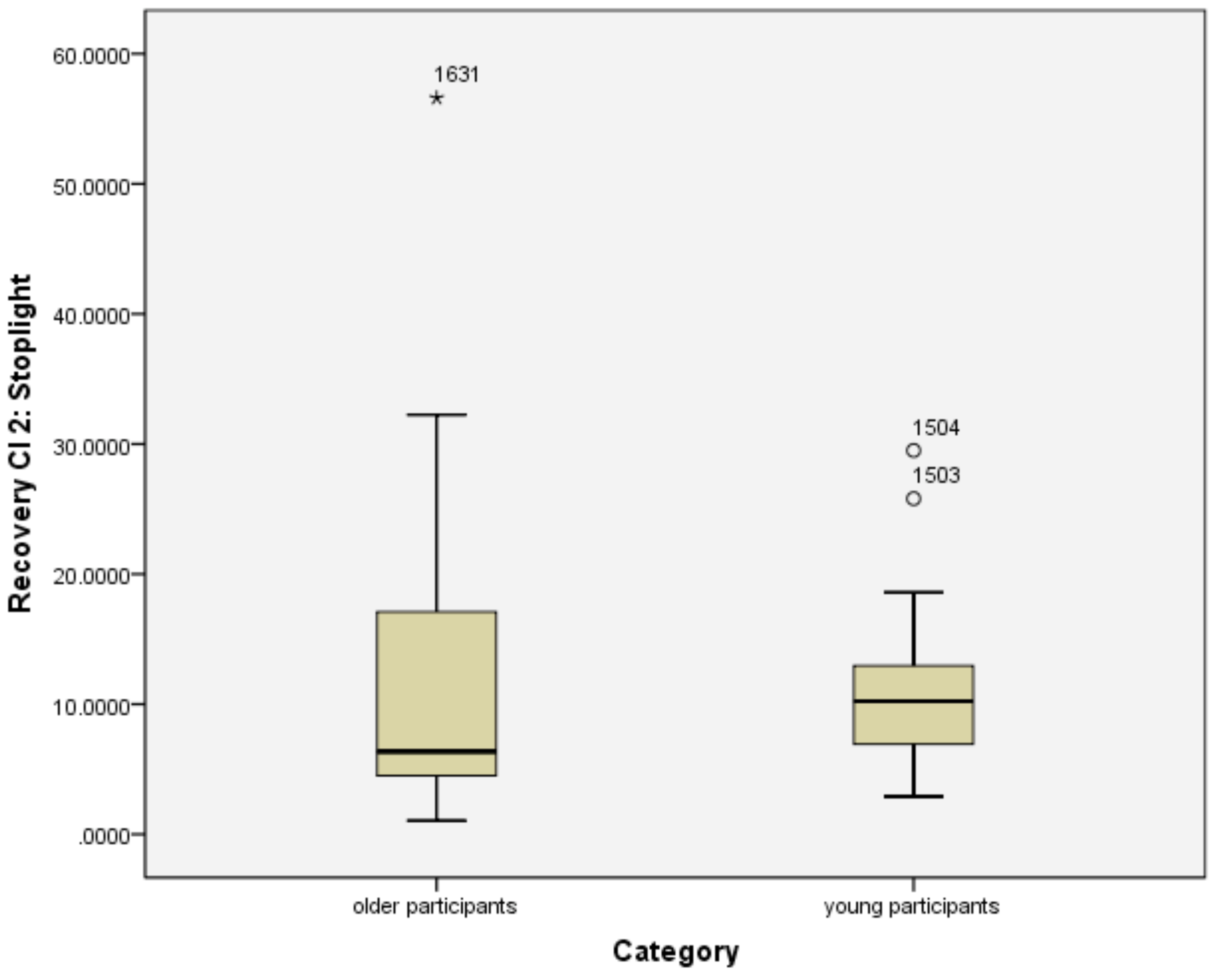

Figure 11. Boxplot for recovery time to CI 2: Stoplight.

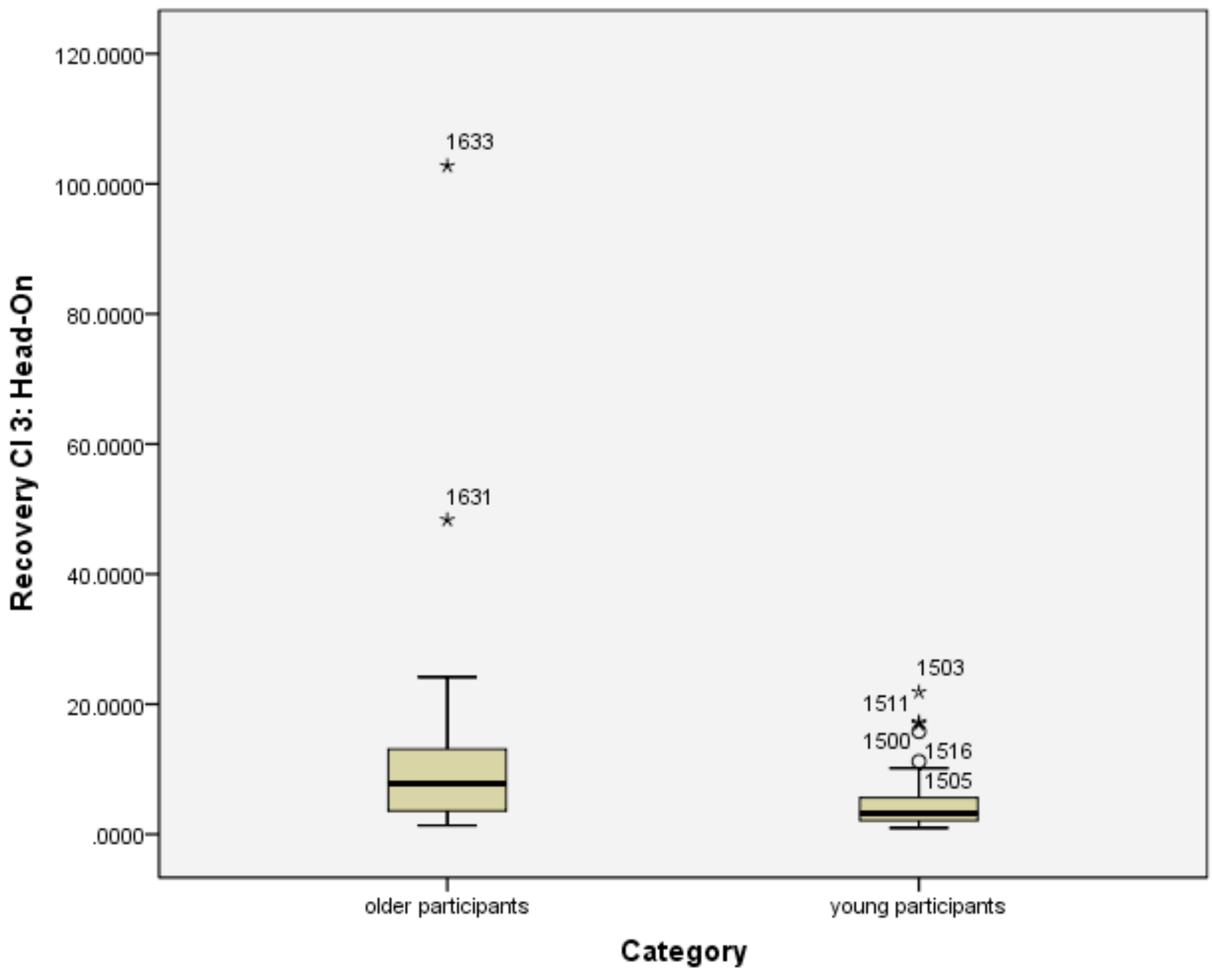

Figure 12. Boxplot for recovery time to CI 3: Head-On.

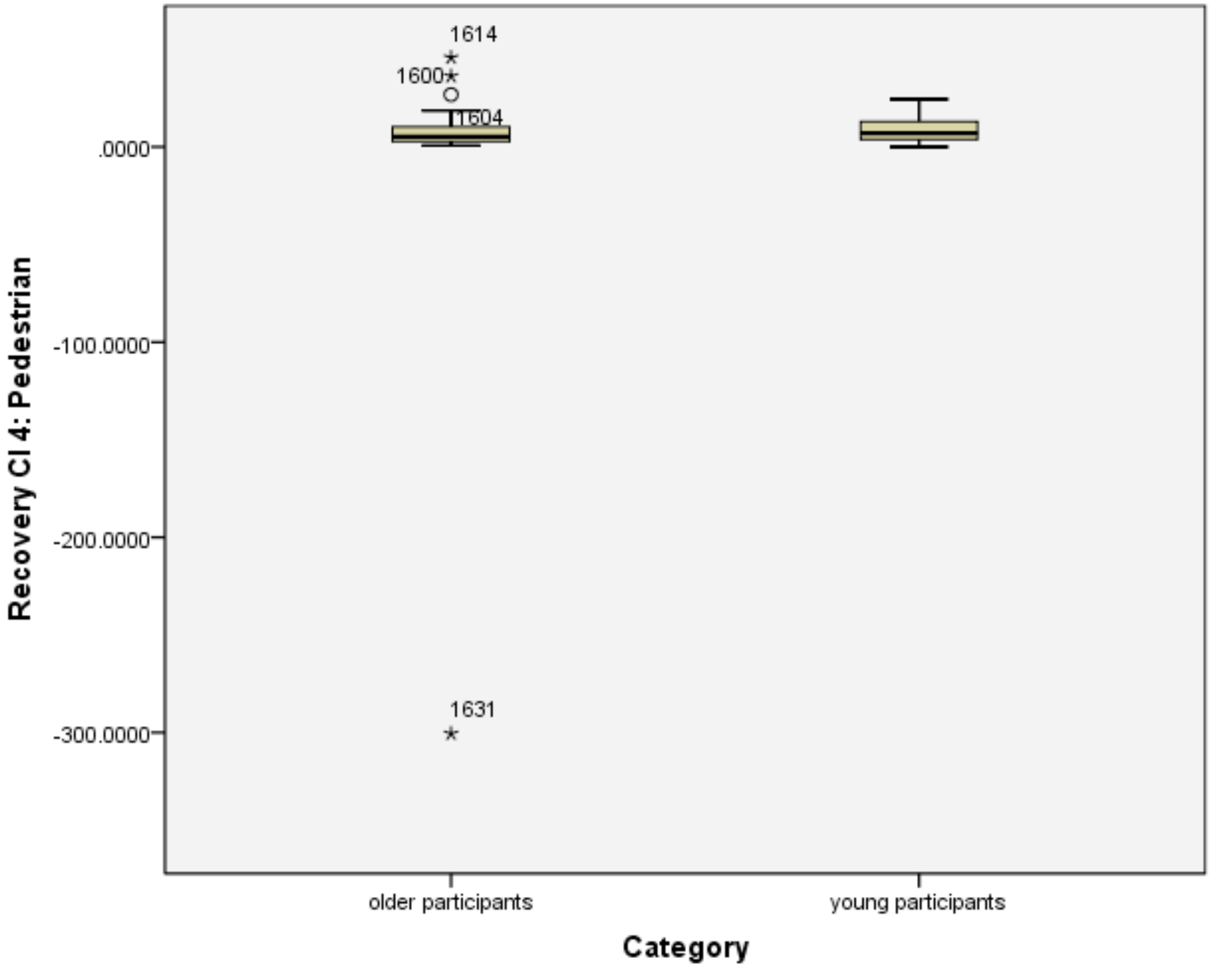

Figure 13. Boxplot for the recovery time to CI 4: Pedestrian.

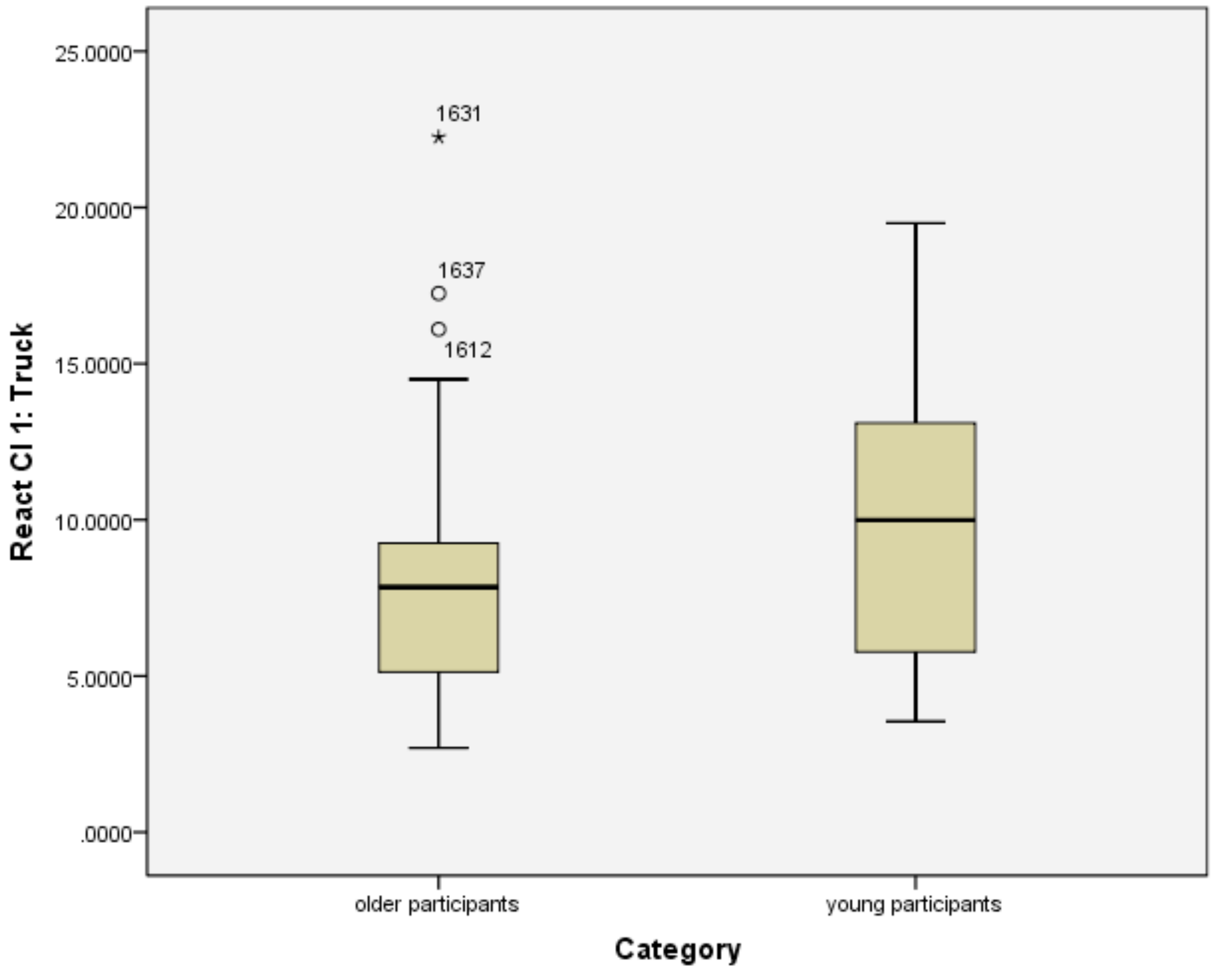

Figure 14. Boxplot for reaction time to CI 1: Truck without outliers.

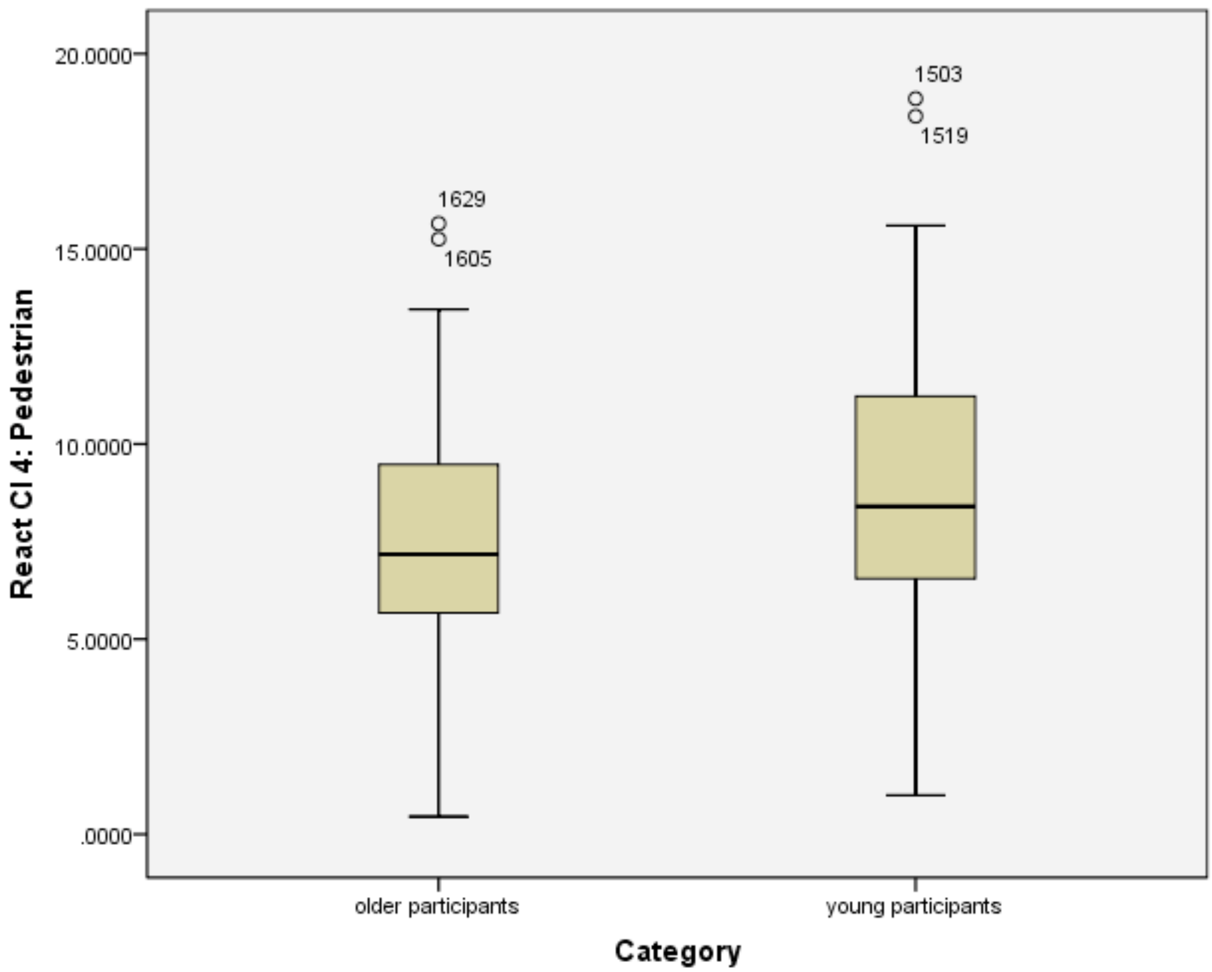

Figure 15. Boxplot for reaction time to CI 4: Pedestrian without outliers.

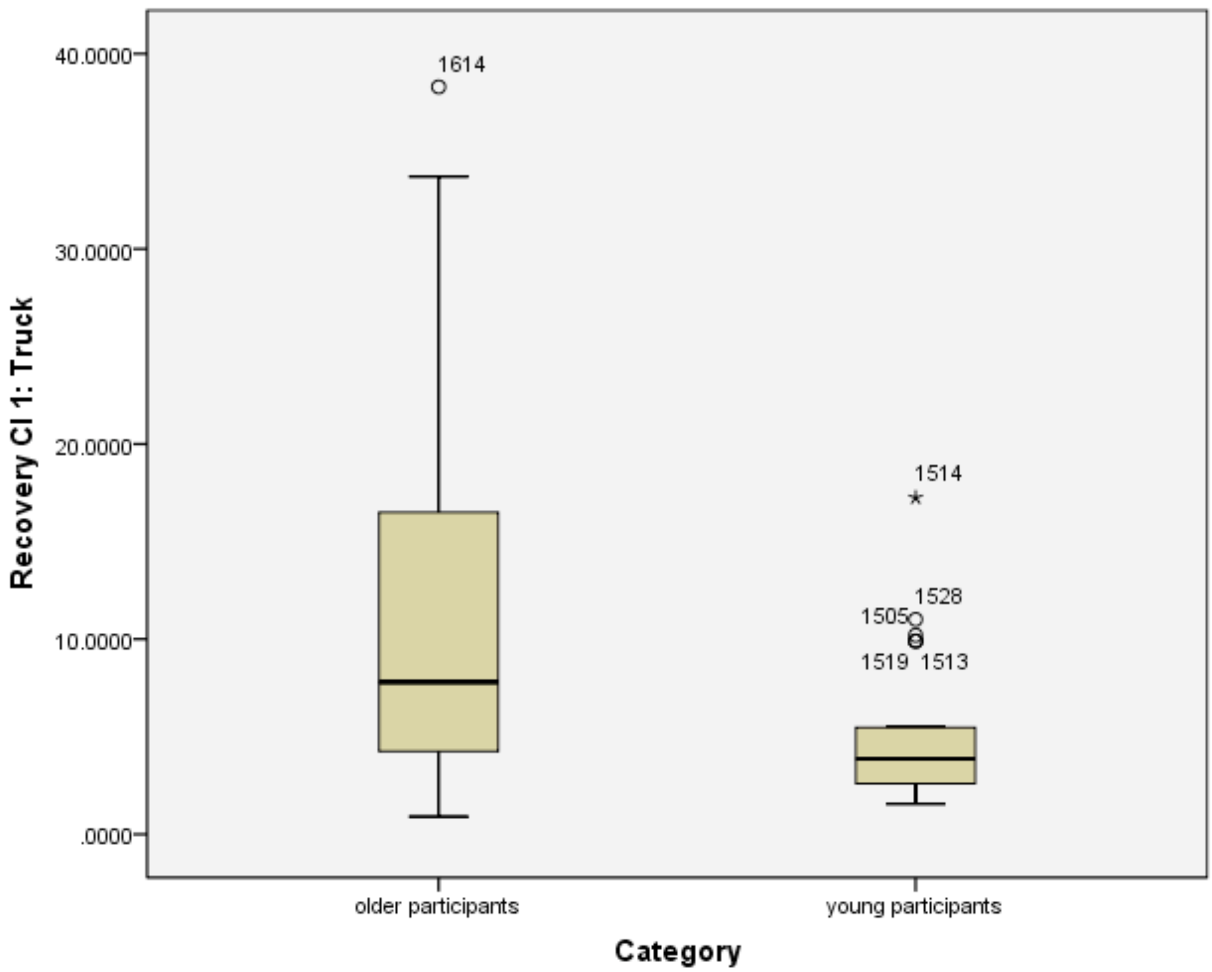

Figure 16. Boxplot for recovery time to CI 1: Truck without outliers.

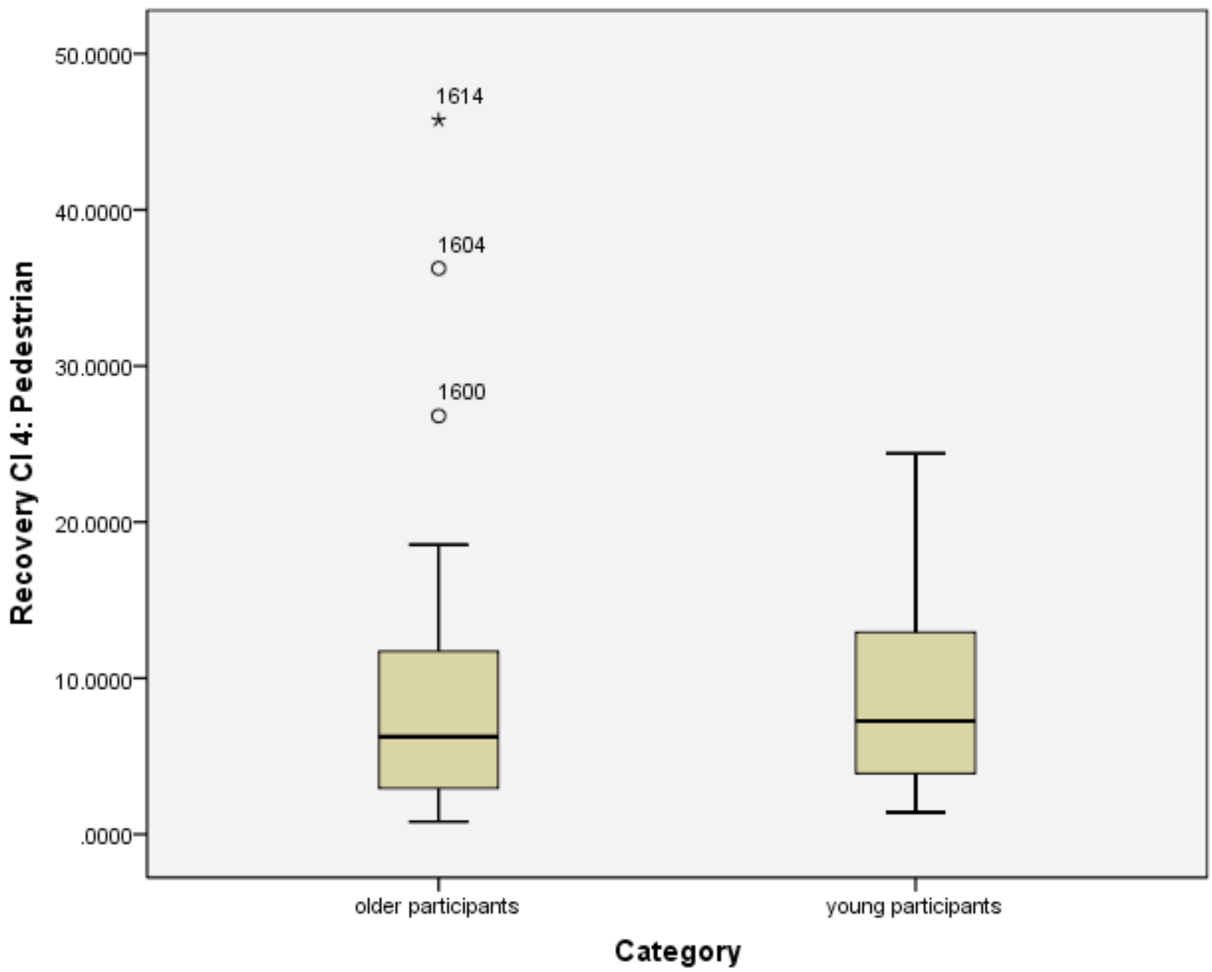

Figure 17. Boxplot for recovery time to CI 4: Pedestrian without outliers.

Appendix A

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
1L-09 Brody Medical Sciences Building• 600 Moye Boulevard • Greenville, NC 27834
Office **252-744-2914** • Fax **252-744-2284** • **www.ecu.edu/irb**

TO: Kristen Davis, BA, c/o Dr. Anne Dickerson, Dept of Occupational Therapy, ECU

FROM: UMCIRB

DATE: August 4, 2011

RE: Expedited Category Research Study

TITLE: "Heart Rate as a Physiologic Response to Scenarios on the Driving Simulator"

UMCIRB #11-0485

This research study has undergone review and approval using expedited review on 8.4.11. This research study is eligible for review under an expedited category number 4 & 7 which include collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. (Studies intended to evaluate the safety and effectiveness of the medical device are not generally eligible for expedited review, including studies of cleared medical devices for new indications.) Examples: (a) physical sensors that are applied either to the surface of the body or at a distance and do not involve input of significant amounts of energy into the subject or an invasion of the subject's privacy; (b) weighing or testing sensory acuity; (c) magnetic resonance imaging; (d) electrocardiography, electroencephalography, thermography, detection of naturally occurring radioactivity, electroretinography, ultrasound, diagnostic infrared imaging, doppler blood flow, and echocardiography; (e) moderate exercise, muscular strength testing, body composition assessment, and flexibility testing where appropriate given the age, weight, and health of the individual and research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(2) and (b)(3). This listing refers only to research that is not exempt.)
The Chairperson (or designee) deemed this **unfunded** study **no more than minimal risk** requiring a continuing review in **12 months**. Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The investigator must adhere to all reporting requirements for this study.

The above referenced research study has been given approval for the period of **8.4.11** to **8.3.12**. The approval includes the following items:

- Internal Processing Form (dated 6.15.11)
- Informed Consent (dated 8.2.11)
- Simulator Sickness Questionnaire
- Driving Habits Questionnaire
- COI Disclosure Form (dated 7.20.11)

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

The UMCIRB applies 45 CFR 46, Subparts A-D, to all research reviewed by the UMCIRB regardless of the funding source. 21 CFR 50 and 21 CFR 56 are applied to all research studies under the Food and Drug Administration regulation. The UMCIRB follows applicable International Conference on Harmonisation Good Clinical Practice guidelines.

Appendix B

Image 1. Driving simulator