THE EFFECT OF CONCUSSION ON REACTION TIME AND DUAL TASKING ABILITY IN A SIMULATED DRIVING ENVIRONMENT

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The purpose of this study was to determine the effect of concussion on drivers' reaction time and dual tasking ability in a simulated driving environment. Testing was performed with a STISIM Model 400 driving simulator. Participants (10 healthy and 10 two weeks to three months post-concussion) were exposed to multiple reaction time scenarios including pedestrian, vehicle, and cyclist incursions. Dual tasking ability was measured using STISIM dual task scenarios. There were longer reaction times in concussed participants ($F(1, 18)$ = 2.072, p = .001, η^2=.600) and a lower number of mean dual task passes in concussed participants ($F(1, 18)$ = 23.145, p = .001, η^2 = .563), both of which were statistically significant. Understanding the effect concussion has on driving ability is the first step to creating a guideline for clinicians to refer to when assessing concussed patients and determining if they are fit to drive.

KEY WORDS: concussion, reaction time, dual tasking, driving

INTRODUCTION: Concussions are mild traumatic brain injuries (mTBIs) that result from a direct or indirect impact to the head (Scorza, Raleigh, & O'Connor, 2012). These functional injuries are caused predominantly by shear stress on the brain tissue due to rotational or angular forces resulting in myriad symptoms that range from headaches and dizziness to difficulty concentrating, impaired memory, and vestibular deficits (Scorza et al., 2012). Concussed individuals may also have deficits in both the orienting and executive control components of the human attention network model, leading to difficulty locating, identifying, and reacting to stimuli (Ponsford & Kinsella, 1992; Stuss et al., 1989). The effect of concussions on driving performance and the ability to perform two activities at the same time (dual tasking) during driving is a relatively new and unexplored field of study. Studies have been performed examining reaction time and dual tasking in driving simulation in healthy participants, but none have been performed using concussed subjects (Drews et al., 2009, Johansson & Rumar, 1971). Furthermore, reaction time in relation to driving after concussion has been examined through personal perception questionnaires and computer based testing, but not in an ecologically valid driving environment (Preece et al., 2010; Preece et al., 2013). It has been established that concussion has a significant effect on reaction time and dual tasking ability, but there is limited literature connecting these factors to a driving environment (Cossette, Ouellete, & McFadyen 2014; DeHann et al., 2007). Therefore, the purpose of this study was to compare driver reaction time and dual tasking ability in concussed and normal healthy populations in a simulated driving environment. This approach is important as it provides an avenue for future research to better understand how concussion alters performance during vehicular operation. It may also aid in the development of a standardized methodology for assessing a concussed driver.

METHODS: Healthy participants (n = 10) were recruited via convenience sampling and concussed participants (n = 10) were recruited by referral from a medical physician through the Lakehead University Concussion Clinic. Participants were excluded from the study if they had psychiatric, motor, or substance abuse disorders that could potentially affect their reaction time, or ability to successfully operate the driving simulator. This information was obtained via a screening questionnaire completed by all participants. Concussed participants, ranging from two weeks to three months post concussive injury, were also assessed at the Lakehead University Concussion Clinic and medically cleared for participation with the use of the Sport Concussion Assessment Tool 3 (SCAT-3). Ethical approval was obtained from Lakehead University's Research Ethics Board. After obtaining informed consent from the participant, a 10 minute orientation drive was completed allowing the individual to familiarize themselves with the control and feel of the driving simulator. During this time, participants were exposed to examples of the dual tasking activities to understand how to successfully respond to the prompts. Once the participant was comfortable with the operation of the simulator, the 20 minute simulation and data collection began. The simulation was based on the City of Thunder Bay road system with traffic and pedestrians present. Weather conditions were clear and visibility was not reduced during the driving simulation. Reaction times were measured during pre-determined scenarios and recorded from the moment the stimulus occurred, to the moment the brake was depressed, or an evasive maneuver was performed. Participants were exposed to several reaction time scenarios. These scenarios included vehicle incursion at intersection, pedestrian incursion from side of the road, sudden braking by a vehicle in front of participant, pedestrian incursion in school zone, braking by a vehicle in front of participant, and animal incursion. During these events, red triangles were displayed over either of the side view mirrors. These triangles were deactivated by the press of a button on either side of the steering column, accounting for the dual tasking component of the reaction time scenarios. During each scenario, the participant was required to safely operate the vehicle and respond appropriately to changes in the environment (e.g., traffic coming to a halt, pedestrians crossing the road, vehicles backing out of driveways). Reaction time data was collected based on the scenario displayed. If the participant was unsuccessful during a dual tasking scenario and came into contact with an on-screen stimulus, he/she continued with the simulation but did not have a second chance at completing that specific activity. This technique was implemented to minimize any learning effect of the pre-programmed scenarios. If a participant experienced symptoms of simulator sickness, the scenario could be paused to allow him/her to take a break from the screen and have something to drink or eat. When the participant felt ready to proceed, the simulation could be resumed from the point of the original pause. If the participant was unable to continue, the simulation was stopped, data collection was terminated, and the data was not included in the analysis.

RESULTS: There was no statistically significant interaction between group (healthy or concussed) and driving scenario on reaction time, $F(3.043, 54.775) = 0.794$, $p = .504$, $\eta^2 = .03$. There was a significant main effect of group type. As depicted in Figure 1, a statistically significant difference in reaction times was found between concussed and healthy participants, $F(1, 18) = 2.072$, $p = .001$, $\eta^2 = .600$.

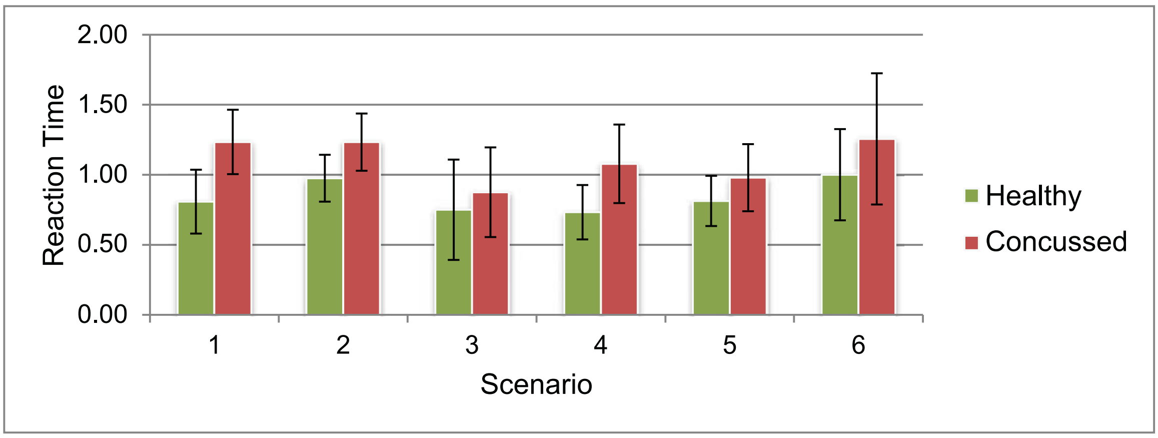

Figure 1: Mean reaction time (seconds) values for healthy and concussed participants. Error bars represent 95% confidence intervals.

There was no statistically significant interaction between group (healthy or concussed) and dual task scenario on dual task reaction time $F(2, 36) = 0.750$, $p = .479$, $\eta^2 = .027$. There was a significant main effect of group type. As depicted in Figure 2, a statistically significant difference in dual task reaction time was found between healthy and concussed participants, $F(1, 18) = 23.145$, $p = .001$, $\eta^2 = .563$.

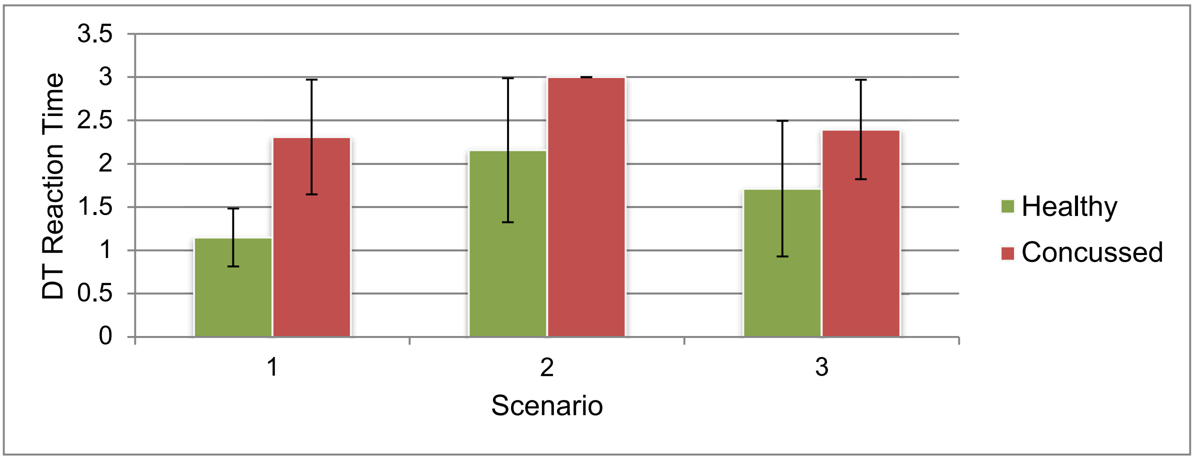

Figure 2: Mean dual task reaction time (seconds) for healthy and concussed participants. Error bars represent 95% confidence intervals. Scenario 2 has no standard deviation reported for the concussed participants due as all participants failed to meet the 3-second threshold to respond to the stimulus.

DISCUSSION: These results highlight important differences in both reaction time and ability to respond to secondary dual task cues in a driving environment between concussed participants and normal healthy controls. With respect to human attention network models, concussed drivers appeared to experience deficits in the orienting network. Orienting network deficits resulted in difficulty with locating cues within a known space before a target or symbol was shown (Ponsford & Kinsella, 1992; Stuss et al., 1989; Spikman, Zomeren, & Deelman, 1996). This potentially affected on the concussed participants' ability to locate the dual task markers and respond correctly in the required amount of time. Deficits in executive control networks, as seen in the concussed participants, led to difficulty determining and acting on stimuli relevant to the current task, such as dual task markers, amidst background stimuli irrelevant to the test (Ponsford & Kinsella, 1992; Stuss et al., 1989). This may have led to the discrepancy in reaction times during the various traffic scenarios and vehicle/pedestrian incursions when compared to the normal healthy sample. During data collection no participants experienced simulator sickness, indicating that this protocol was safe and well tolerated by the patient population. While these findings were statistically significant, it is important to note that reaction times and dual task reaction times may have been affected by mood, attentiveness, motivation, and the relative health of the subjects. This study is limited by the broad and subjective nature of concussion. The subjective symptoms reported by the concussed participants varied. These varied symptoms, combined with the wide-ranging time frame since injury may have lead to a large range of scores for both reaction time and dual task pass rates as more participants were tested.

CONCLUSION: The purpose of this study was to compare driver reaction time and dual tasking ability in concussed and normal healthy populations in a simulated driving environment. These preliminary results revealed statistically significant differences between the groups for both reaction time and dual task reaction time. These results are consistent with previous literature reporting reaction time and dual task deficits for concussed individuals in non-driving environments. Furthermore, these results are in accordance with the deficits concussed individuals experience in the orienting and executive control networks as indicated by the human attention network model. Understanding the effect concussion has on safe driving ability is the first step to creating a standardized guideline for clinicians to use when assessing concussed patients and determining if they are fit to drive. Standardized guidelines would also benefit individual patients by ensuring both their own safety and that of others sharing the road. This research also assists in opening an avenue for future research to explore relationships between brain injury reconstruction techniques using kinematic measures and driving ability. Future research will include more concussed participants to strengthen the results of the study and equalize the number of participants in each group.

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