COMPUTATIONAL MODEL TO PREDICT THE EFFECTS OF COGNITIVE AND NEUROMUSCULAR IMPAIRMENTS ON DRIVING

Benjamin L. Long[1,3], A. Isabella Gillespie[2,3], Martin L. Tanaka[2,3]

[1]Department of Physical Therapy, Winston-Salem State University, Winston-Salem, NC
[2]Department of Orthopaedic Surgery, Wake Forest University, Winston-Salem, NC
[3]Human Performance and Biodynamics Laboratory, a collaboration between
Wake Forest University School of Medicine and Winston-Salem State University
Email: mtanaka@wfubmc.edu

INTRODUCTION

Motor vehicle accidents are the leading cause of death for United States citizens age four through 34 years[1]. Mental distractions and physical impairments can further increase the risk of accidents by affecting a driver's ability to control the vehicle and react to various distractions. In this study, cognitive challenges and physical impairments were imposed and their affect on cognitive, neuromuscular, and total reaction time was evaluated. From these measured results, we developed a linear mathematical model that may be used to quantitatively predict drivers' performance under a variety of possible driving conditions. Predictions were not limited only to conditions tested, but rather, our model may be used to predict reaction speed for any linear combination of these test conditions. We believe that this is the first model to use this linear combination approach to predict drivers' reaction speed.

METHODS

Experiment

Twenty-four (8 female, 16 male) participants from the university and surrounding area volunteered to participate in the study. Group one (n=12) was tested to evaluate the effects of dual cognitive tasks on driving reaction speed, cell phone talking and texting. Group two (n=12) was used to evaluate the effects of a physical impairment on reaction speed, a fixed knee brace (FKB). Group two was also tested with a FKB and while talking a cell phone. This condition did not go into the development of the model but instead was used for model verification.

All trials were performed on a custom built driving reaction speed tester (DRST). A data acquisition card (National Instruments, Austin, Texas) installed in a personal computer was used to record (1000 Hz) the voltage associated with the positions of the gas, brake, and clutch pedals. After testing was completed, the test files were accessed using Matlab software (MathWorks; Natick, Massachusetts). Full braking time (FBT) was calculated from the sum of the cognitive reaction time (CRT), foot movement time (FMT), and break travel time (BTR).

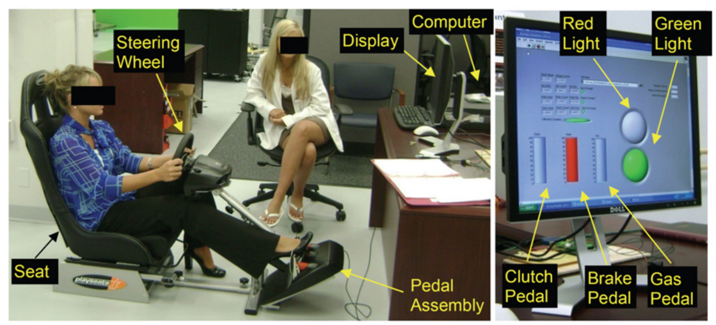

Figure 1: Driver Reaction Speed Tester (DRST).

Computational Model

A linear mathematical model was developed to predict the reaction speed under various testing conditions. The predicted full braking time, *PT*, for a specific set of test conditions was,

$$PT = N_j + \sum_{m=1}^{n} A_m + \sum_{m=1}^{n} B_m + \sum_{m=1}^{n} C_m$$

where N_j is the average FBT under normal conditions for participant *j*. A_m, B_m, and C_m are the effects of each modifier on the CRT, FMT and BTT, respectively. The applied modifying factor is *m,* and *n* is the total number of modifying factors. In this study, conditions primarily affecting cognitive reaction speed were talking (*m*=1) or texting (*m*=2) on a cellular phone. The main modifier associated with musculoskeletal reaction speed was the physical impairment of a FKB (m=3).

A one-way ANOVA was used to determine the individual effect of cell phone talking, cell phone texting, and a fixed knee brace on CRT, FMT, BTT, and FBT. All statistics were analyzed using SPSS software (SPSS Inc.; Chicago, Illinois) with significance set as $p<.05$ for all tests.

RESULTS AND DISCUSSION

A threshold detection method was used to automatically find the time when each pedal was released and depressed (Figure 2). The net effect of each test condition on CRT, BTT, and FMT was calculated from the experimental results by subtracting the mean value for the test condition from the mean value for normal driving. These net effects were used as calibration parameters in the mathematical model (Table 1).

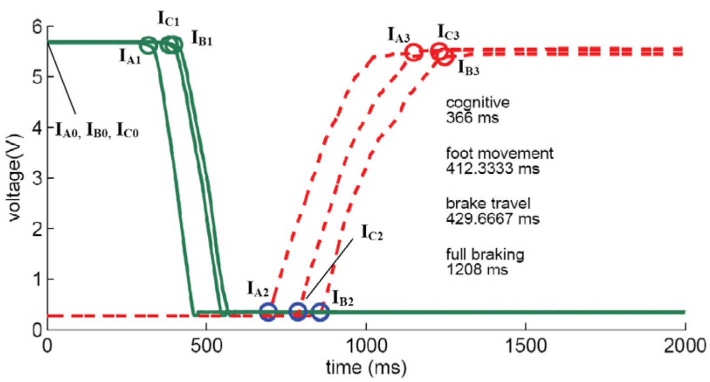

Figure 2: Reaction speed data. I_{A0}, I_{B0}, and I_{C0} mark the beginning of each individual reaction speed test within the trial. The second subscript, 1, 2, or 3, indicate the end of the cognitive, foot movement, and brake travel portion of the reaction speed test, respectively.

Table 1: Mathematical Model Calibration Parameters

Condition	Symbol	Reaction Speed Cost
Cell Phone Talking	A_1	122 ms
	B_1	0 ms
	C_1	0 ms
Texting	A_2	268 ms
	B_2	34 ms
	C_2	25 ms
Fixed Knee Brace	A_3	16 ms
	B_3	49 ms
	C_3	55 ms

The model was used to predict driving reaction speed for an untested condition, talking on a cell phone while wearing a FKB. This test condition was measured experimentally and the accuracy of the model evaluated. Recall that this condition was not used in the development of the model. The model predicted full braking time within 3% of the measured value (Figure 3).

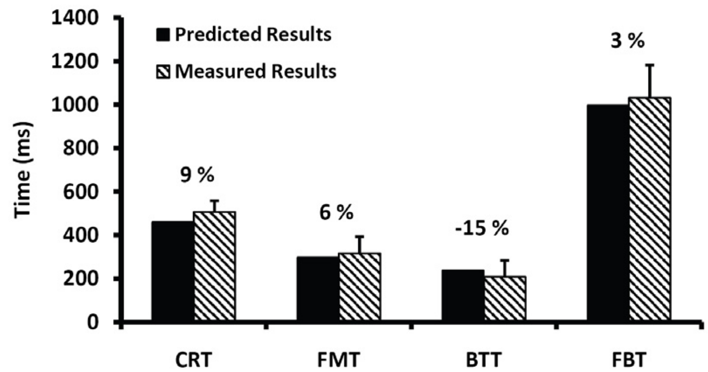

Figure 3: Comparison of model predicted and actual measured results for drivers' reaction time. The linear model was able to predict the full braking time within 3% of the actual measured value.

The use of the linear model is limited by its' inability to account for complex interactions that may occur between modifying variables. In addition, little information is known about the effect of participant learning under various testing conditions. These limitations will be addressed in future versions of the model.

CONCLUSIONS

This abstract presents a mathematical model that may be used to predict driving reaction speed for a variety of influencing conditions. Although only a few influential conditions were evaluated, we present a general approach that may be expanded to include other types of distractions, impairments, and environmental conditions.

REFERENCES

1. NHTSA. (2008). *Motor Vehicle Traffic Crashes As a Leading Cause of Death in the United States, 2005*. Washington, DC 20590: National Highway Traffic Safety Administration.