MID-AMERICA TRANSPORTATION CENTER

Report # MATC-KUMC: 155-2

Final Report
WBS:25-1121-0005-155-2

Assessing and Improving the Cognitive and Visual Driving Fitness of CDL Drivers - Phase II

Shelley B. Bhattacharya, DO, MPH
Principal Investigator
Department of Family Medicine
University of Kansas Medical Center

Abiodun Akinwuntan, PhD
Senior Director
School of Health Professions

Hannes Devos, PhD
Research Associate/co-author
School of Health Professions

Iarina Devos
Research Assistant/co-author
Department of Family Medicine

Fernanda Ribas
Student Research Assistant, M4

Robert Gibson
Student Research Assistant, M3

Gabrielle Fangman
Student Research Assistant, M3

Bingjie Li
Student Research Assistant, M3

Rachel Jenkins
Student Research Assistant
co-author, M3

2019

A Cooperative Research Project sponsored by
U.S. Department of Transportation- Office of the Assistant Secretary for Research and Technology

Assessing and Improving the Cognitive and Visual Driving Fitness of CDL Drivers – Phase II

Shelley B. Bhattacharya, DO, MPH
PI
University of Kansas Medical Center
Department of Family Medicine

Abiodun Akinwuntan, PhD
Senior Director
University of Kansas Medical Center
School of Health Professions

Hannes Devos, PhD
Research Associate/co-author
University of Kansas Medical Center
School of Health Professions

Iarina Devos
Research Assistant/co-author
University of Kansas Medical Center
Department of Family Medicine

Fernanda Ribas
Research Assistant
University of Kansas School of Medicine
M4

Robert Gibson
Research Assistant
University of Kansas School of Medicine
M3

Gabrielle Fangman
Research Assistant
University of Kansas School of Medicine
M3

Bingjie Li
Research Assistant
University of Kansas School of Medicine
M3

Rachel Jenkins
Research Assistant/co-author
University of Kansas School of Medicine
M3

A Report on Research Sponsored by the

Mid-America Transportation Center

University of Nebraska–Lincoln

September 2019

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. 25-1121-0005-155-2	**2. Government Accession No.**	**3. Recipient's Catalog No.**

4. Title and Subtitle Assessing and Improving the Cognitive and Visual Driving Fitness of CDL Drivers - Phase II	**5. Report Date** September 30, 2019 **6. Performing Organization Code** n/a
7. Author(s) Shelley B. Bhattacharya https://orcid.org/0000-0002-7275-2362 Abiodun Akinwuntan https://orcid.org/0000-0002-0167-685X Hannes Devos, Fernanda Ribas, Robert Gibson, Rachel Jenkins, Bingjie Li, Gabrielle Fangman and Iarina Devos	**8. Performing Organization Report No.** 25-1121-0005-155-2
9. Performing Organization Name and Address University of Kansas Medical Center 3901 Rainbow Blvd. Kansas City, KS, 66160	**10. Work Unit No.** **11. Contract or Grant No.** 69A3551747107, subaward with the University of Kansas, Lawrence
12. Sponsoring Agency Name and Address Office of the Assistant Secretary for Research and Technology 1200 New Jersey Avenue, SE Washington, DC 20590 United States	**13. Type of Report and Period Covered** MATC Final Report, Year 2 October 1, 2018-September 30, 2019 **14. Sponsoring Agency Code** RiP No. 91994-35

15. Supplementary Notes
Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. Abstract
Driving is a highly dynamic task that requires intact cognitive and visual skills to perform safely. Driving a commercial motor vehicle requires careful planning and consideration. These additional factors are highly dependent on cognitive and visual skills for accuracy. This study aims to identify specific clinical tests that correlate well with commercial driver's license (CDL) driving performance. During year 2 of this proposal, we refined our clinical fitness-to-drive assessment battery and recruited 25 individuals with commercial driver's licenses. We developed a two-hour driving fitness assessment battery consisting of tests that have been shown in the literature to be reliable and valid measures of driving-related cognitive and visual skills in drivers, with appropriate scoring systems and recommendation guidelines. On-the-road driving performance was assessed by volunteering annual elog data and a driver's self-assessment. The goals of this year of the study were to: 1) Approach local and national companies to continue to recruit CDL drivers, 2) Assess the cognitive and visual fitness of CDL drivers by implementing the battery of tests listed above, 3) Confidentially share the results with each CDL driver , 4) Share potential risk factors that contribute to unsafe driving with the CDL driver and provide resources to improve any recognized deficits, 5) Begin collecting the Year 2 driving performance and test data on our subjects recruited during Year 1, and 6) Invite medical students to join our research team to assist with recruitment and assessments. To date, we have 25 subjects who completed their Year 1 assessments, and we have begun year 2 testing from our year 1 subjects. During years three to five, we plan to develop a sensitive measure, using task-evoked pupillary response (TEPR), of cognitive and visual alertness that can indicate cognitive overload capable of resulting in an accident. Over the course of the grant, we anticipate the study will identify the top five clinical tests that can correlate well with on-the-road driving safety of CDL drivers and provide data on the utility of TEPR as a measure of driver alertness. The technology transfer products this study hopes to accomplish are to: 1) Improve the annual Department of Transportation (DOT) physical by informing the DOT of these specific tests correlated with CDL driving safety, 2) Provide commercial companies with these tools to improve the safety of their CDL drivers, and 3) Begin design of an alert system that will notify all emergency medical services within a specific radius of an accident of the nature of the hazardous materials being hauled by the commercial vehicle and the extent of damage.

17. Key Words Safety and Security: Safety (Ha), Crashes (Hb), Risk (Hk), CDL	**18. Distribution Statement** No restrictions.

19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Classified	**21. No. of Pages** 12	**22. Price**

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Table of Contents

List of Tables

List of Abbreviations

Commercial Driver's License (CDL)
Commercial Motor Vehicle (CMV)
Federal Motor Carrier Safety Administration (FMCSA)
Iowa Department of Transportation (IaDOT)
Kansas Department of Transportation (KDOT)
Mid-America Transportation Center (MATC)
Missouri Department of Transportation (MoDOT)
National Institute for Occupational Safety and Health (NIOSH)
Nebraska Department of Roads (NDOR)
Nebraska Transportation Center (NTC)
Transportation Research Board of the National Academies (TRB)
University Transportation Center (UTC)
United States Department of Transportation (USDOT)
Useful Field of View (UFOV)

Acknowledgments

This project would not have been possible without the unity of our research team and our collaborative relationship with Dr. Larry Rilett from the University of Nebraska-Lincoln and Dr. Steven Schrock from the University of Kansas-Lawrence.

Disclaimer

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated in the interest of information exchange. The report is funded, partially or entirely, by a grant from the U.S. Department of Transportation's University Transportation Centers Program. However, the U.S. Government assumes no liability for the contents or use thereof.

Abstract

Driving is a highly dynamic task that requires intact cognitive and visual skills to perform safely. Driving commercial motor vehicles requires even more careful planning and consideration. These additional factors are highly dependent on cognitive and visual skills for accuracy. This study aims to identify specific clinical tests that correlate well with commercial driver's license (CDL) driving performance. During year 2 of this proposal, we refined our clinical fitness-to-drive assessment battery and recruited 25 individuals with commercial driver's licenses. We developed a two-hour driving fitness assessment battery consisting of tests that have been shown in the literature to be reliable and valid measures of driving-related cognitive and visual skills in drivers, with appropriate scoring systems and recommendation guidelines. These tests consisted of the Snellen Maze test, Trails A and B, range of motion, gait speed and the Montreal Cognitive Assessment (MoCA). On-the-road driving performance was assessed by volunteering annual elog data and a driver's self-assessment. The goals of this year of the study were to: 1) Approach local and national companies to continue to recruit CDL drivers, 2) Assess the cognitive and visual fitness of CDL drivers by implementing the battery of tests listed above, 3) Confidentially share the results with each CDL driver , 4) Share potential risk factors that contribute to unsafe driving with the CDL driver and provide resources to improve any recognized deficits, 5) Begin collecting the Year 2 driving performance and test data on our subjects recruited during Year 1, and 6) Invite medical students to join our research team to assist with recruitment and assessments. To date, we have 25 subjects who completed their first year assessments, and we have begun year 2 testing from our year 1 subjects. During years three to five, we plan to develop a sensitive measure, using task-evoked pupillary response (TEPR), of cognitive and visual alertness that can indicate cognitive overload capable of resulting in an

accident. Over the course of the grant, we anticipate the study will identify the top five clinical tests that can correlate well with on-the-road driving safety of CDL drivers and provide data on the utility of TEPR as a measure of driver alertness. The technology transfer products this study hopes to accomplish are to: 1) Improve the annual Department of Transportation (DOT) physical by informing the DOT of these specific tests correlated with CDL driving safety, 2) Provide commercial companies with these tools to improve the safety of their CDL drivers, and 3) Begin design of an alert system that will notify all emergency medical services within a specific radius of an accident of the nature of the hazardous materials being hauled by the commercial vehicle and the extent of damage.

Chapter 1 Purpose, Background, and Rationale

One of the cardinal missions of the Federal Motor Carrier Safety Administration (FMCSA) of the United States Department of Transportation is to improve safety on our nation's highways. That includes reducing the number of accidents that involve Commercial Driver's License (CDL) drivers. Such accidents have a high potential to cause serious harm to the public and the environment. In addition to the several initiatives that have been put in place by the FMCSA to reduce accidents involving commercial vehicles, we aim to address CDL driver safety by (i) determining cognitive and visual fitness to improve driver fitness, and rehabilitating pertinent components of drivers who drive commercial vehicles; (ii) developing a sensitive measure of cognitive and visual alertness that can indicate cognitive overload capable of resulting in an accident; (iii) using a simulator, begin designing an alert system that will notify all emergency medical services within a specific radius of an accident of the nature of the hazardous materials being hauled by the commercial vehicle and the extent of damage.

The Mid-America Transportation Center (MATC) was designated by the United States Department of Transportation as the Region VII University Transportation Center (UTC) in 2017. MATC is a consortium comprised of the University of Nebraska-Lincoln, University of Nebraska Omaha, University of Nebraska Medical Center, University of Kansas, University of Kansas Medical Center, Missouri University of Science and Technology, University of Iowa, Nebraska Indian Community College, and Lincoln University. MATC's partners include the Iowa Department of Transportation (IaDOT), the Kansas Department of Transportation (KDOT), Missouri Department of Transportation (MoDOT), the Nebraska Department of Roads (NDOR), the United States Department of Transportation (USDOT), and various private and public sector transportation organizations.

This project is needed to meet MATC's vision to become a nationally recognized center of transportation excellence focused on developing new knowledge, innovative solutions, and the next generation of transportation professionals necessary to sustain the U.S. transportation system in a manner that is safer, more effective, more efficient, environmentally friendly, and sustainable. CDL drivers are becoming increasingly prominent; maintaining their cognitive and visual fitness is essential for their safety and the safety of others sharing the road.

1.1 Aim and Hypothesis

Driving is a highly dynamic task that requires intact cognitive and visual skills to perform safely. Driving commercial vehicles, such as buses or trucks, require even more careful planning and consideration. Such planning and consideration are highly dependent on cognitive and visual skills for accuracy.

The study aims are to:

1) Assess CDL drivers' cognitive and visual fitness,
2) Establish the usefulness and effectiveness of these tests to drivers before embarking on the journey,
3) Identify potential risk factors that contribute to unsafe driving, and
4) Evaluate the effect of an intervention program to improve reduced visual, cognitive, and driving skills.

The study hypotheses are:

1) By correlating testing measures with on-the-road driving performance, we can develop a testing rubric of five tools that clinicians can use to optimally predict driving safety, and
2) By testing task-evoked pupillary responses, we can determine if it can be used as a suitable measure of cognitive load when driving.

1.2 Study Significance

We anticipate that this study will be helpful in identifying CDL drivers who have cognitive and/or visual impairments that may make driving a commercial vehicle unsafe. A unique aspect of this part of the study is the possibility of improving driving fitness by offering drivers with demonstrated cognitive and visual deficits resources to improve their performance.

Moreover, this project will also meet Mid-America Transportation Center's research goal to make fundamental advancements in basic and theoretical research related to improving the safety of the US and Region VII transportation systems. A key focus is to ensure that this research product will be implemented by regional and national transportation agencies and companies.

1.3 Literature Review

There are approximately 1.7 million long-haul truck drivers in the USA, either for hire or in private fleets (Hege et al., 2015). Truck driving is the second most common occupation in the USA (following retail sales), employing 1 in 35 adult men. Commercial motor vehicle (CMV) drivers, including bus drivers, make up a substantial proportion of the workforce, however, it is anticipated there will be a shortage of CDL drivers in the coming years in the United States. Many studies in the US have examined crash risk in CMV (Chen & Xie, 2014). Data from the US show that truck drivers account for 16–20% of all crashes, costing billions of dollars annually (Mayhew et al., 2011). While reducing the number of injurious and fatal accidents is paramount to public safety, determining causative factors are equally important in reducing crash risk.

One review found associations between fatigue and crash risk as well as other factors related to truck design and maintenance, such as unsecure cargo and weather conditions (Robb, Sultana, Ameratunga, & Jackson, 2008). Yet, this review was not inclusive of long-haul truck drivers; it included taxi drivers, professional drivers, company car drivers, as well as studies related to medical personnel and nurses. The review also included studies from countries that are not analogous to the North American model (Robb et al., 2008).

Recent US studies show that factors related to demographics as well as health and wellness are associated with crash risk including age, gender (men), low back pain, cardiovascular disease, stress, untreated sleep apnea and diabetes, as well as obesity (Apostolopoulos et al., 2012; Apostolopoulos, Sonmez, Shattell, & Belzer, 2010; Apostolopoulos et al., 2011). Thus, CDL drivers are considered a vulnerable or high-risk segment of the population by the US Federal Motor Carrier Safety Administration (FMCSA), the Transportation Research Board of the National Academies (TRB), and the National Institute for Occupational Safety and Health (NIOSH). CDL drivers are plagued with high rates of disease often attributed directly to the nature of the job (Lemke, Apostolopoulos, Hege, Sönmez, & Wideman, 2016).

The work environment exposes all CDL drivers to long work hours (up to 14 hours/day), prolonged sitting, excessive noise and vibration and generally unhealthy lifestyles (Lemke et al., 2016). CDL drivers are more likely to use tobacco, to be physically inactive, to have poor diets, and to have disrupted sleep cycles and higher levels of stress), leading to an increased risk of cardiovascular disease and psychological and musculoskeletal disorders compared to the general population (Apostolopoulos et al., 2012). These risk factors and conditions, particularly among long-haul drivers, can produce work-place injuries and impact work productivity and driving performance.

Taking the above factors into consideration, the average life expectancy of CDL drivers in the US is 12–20 years lower than the general population (Crizzle et al., 2017). The first International Conference on Commercial Driver Health and Wellness was sponsored by the

FMCSA, The US Department of Transportation and NIOSH in 2010. Several priority areas emerged from this conference, particularly the need for a better understanding of the combined impact of multiple risk factors (i.e., irregular schedules, long hours of work, poor diet and nutrition, stress) on driver health and wellness, as well as productivity and safety.

While there is consensus that CDL drivers are an at-risk population for poorer health, there has been no critical appraisal of the motor, cognitive, and visual determinants of driving safety. This study will delve into this arena.

Chapter 2 Methodology and Findings

Drivers over age 18 with an active CDL license were recruited and completed a 120-item battery of assessments. Questions were a series of items to: 1) Assess their cognitive and visual fitness, 2) Provide a self-assessment of their driving, and 3) Identify potential risk factors that contribute to unsafe driving. All subjects were asked to return for a one and two-year follow-up assessment with each participant being given the same tests but in randomized order to prevent bias and to limit confounding factors. The total sample size goal was 85 and 25 have been completed to date. Participants who were unable to provide written informed consent were excluded from the study results. Laboratory testing was not needed in this study.

2.1 Methodology and Study Procedure

Participants were recruited to the University of Kansas Medical Center during years 2-5 to administer a battery of cognitive and visual tests. Participants received $50 compensation for each visit for their time and effort. Test results were shared only with the subjects and did not affect their professional licensing status.

Each study participant underwent all procedures and tests on the same day. The estimated time for testing evaluation, excluding informed consent overview, was no more than two hours. Informed consent was obtained prior to participation in the study, during the scheduled time of their testing session. The informed consent document detailed the procedures and rights of the individual partaking in the study. Any subject who found the procedures objectionable for any reason was given the opportunity to terminate participation as described above. To date, this has not occurred for any subjects. In addition, subjects were informed that they can discuss any questions they have about the research procedures or their performance with the research investigators.

Prior to beginning each testing session, demographic and clinical information including age, sex, BMI, blood pressure, level of education, and driving history was collected for each subject. As a part of each subject's scheduled testing session, they underwent a series of cognitive, visual, and physical assessments. These assessments included the following:

2.1.1 Cognitive assessment (20 minutes)

The cognitive assessment included the Stroke Drivers Screening Assessment (Akinwuntan et al., 2013), the Useful Field of View (Edwards et al., 2006), the Montreal Cognitive Assessment/MOCA (Nasreddine et al., 2005), and Trail Making Tests A and B.

2.1.2 Visual assessment (5 minutes)

The Keystone vision screener was used to assess visual acuity, depth perception, visual field, glare recovery, color perception, depth perception, and eye coordination (stereopsis).

2.1.3 Range of motion and gait speed (5 minutes)

A standard physical exam including range of motion testing and gait speed was performed.

2.1.4 Simulator assessment (20 minutes)

Subjects completed an evaluation in a driving simulator. This evaluation comprised a 20-minute drive in daily-life traffic while obeying the rules of the road. Driving abilities under low and high cognitive demand, and complex brake response time were assessed. Participants were asked to accelerate to 45 miles per hour, maintain this speed, then safely respond to a stop sign by coming to a complete stop. One practice trial and four test trials were used. Average seeing time (time from presentation of stop sign to removing foot from accelerator pedal), average movement time (removing foot from accelerator to the brake pedal), and average brake response time (time to a complete stop) were calculated.

2.1.5 Pupil recording

During the simulator tests, raw pupillary size of the left and right eye will be recorded using a head mounted eye tracker (Tobii Pro Glasses 2, (Tobii Inc, Sweden)) at 60 Hz. Corrective glasses will be fitted on the eye tracker for people who are near- or far-sighted. EyeWorks™ software (EyeTracking, Inc) will be used to calculate the Index of Cognitive Activity (ICA). This ICA is scored on a continuous scale from 0 (no cognitive workload) to 1 (maximum cognitive workload) by transforming the pupil diameter through signal processing algorithms of wavelet analysis (Marshall, 2007). Other variables that may also affect pupillary response, such as lighting, accommodation, and stress, will be filtered out by the ICA algorithm and by exposing all subjects to identical test conditions.

Video recordings of the scene camera from the eye tracker will be timestamped to mark the beginning and end of the simulator tests. Mean ICA, peak ICA, and standard deviation (SD) of ICA of both eyes were used as outcome variables.

2.2 Findings and Revisions

Year Two was focused heavily on subject recruitment. We contacted local and national vendors, medical DOT physical sites, government entities and corporations that employ the majority of the CDL drivers in the Kansas City area. Our team presented at local school bus monthly meetings, truck stops, local trucking, petroleum, food and refuse collection companies. We advertised at major truck rest stops in the metropolitan area and emailed CDL associations such as the Owner-Operator Independent Drivers Association.

We have also worked with the Frontiers/ Heron research database at the University of Kansas Medical Center and received a list of 96 potential participants from their database, 11 of which completed the assessment.

In total, we have spoken to 174 potential participants, of which 25 have completed assessments. Some have come from within the area, some from out-of-state. Overall, they have had a good experience and have notified their colleagues.

2.3 Results

Significant demographic values were: 92% of our participants were male, average age was 50, most common class of medications was for hypertension (high blood pressure), and Body Mass Index (BMI) was 32.4, falling within the obese range (BMI over 30).

All results were discussed with the subjects individually on each visit. The protocol we followed for providing recommendations is described in the table below. Those that failed 50% or more of their tests were asked to receive a full formal evaluation by their primary care physician; those that failed 25-50% of their tests received advice to begin rehabilitation with physical or occupational therapy; those that failed under 25% of the tests had a low cause for concern. Passing scores for each test were determined by their individual cut-offs, as noted in the literature. Table 1 summarizes the recommendation protocol.

Table 2.1 Threshold cut-offs for the variables missed

Threshold of items missed	**Number of variables missed (of total 10)**	**Recommendation**
≥ 50%	≥ 5	Needs full formal evaluation by primary care provider.
25-49%	3-4	Advice for referral to rehabilitation
< 25%	1-2	Low cause for concern

Of the tests listed above, rehabilitation options offered are described in Table 2.2.

Table 2.2 Rehabilitation options offered with each test measure

Test	Rehabilitation Option
UFOV	Physical Therapy
SDSA	Simulator training
TMT-A	Simulator training
TMT-B	Simulator training
Visual Acuity without cues	Referral to Ophthalmology
MOCA	Simulator training
Maze	Simulator training
Rapid Pace Walk	Simulator training, Physical Therapy
Simulator: Driving Performance	Simulator training
Simulator: Reaction Time	Simulator training

Chapter 3 Conclusions and Recommendations

After completing IRB approval and legal clearance during our first year, this year was focused on recruitment. The entire team was involved with recruitment. We created contacts with the Kansas Highway Patrol, the National Motor Carriers Association, the Kansas Motor Carriers Association, and multiple companies. Recruitment efforts to promote our study have led to the revision of our inclusion criteria to include all participants over 18 years of age who possess a current CDL.

Prospective participants received compensation for the time and travel required to participate in the study. During this second year, with additional funds provided by the Research Institute at the University of Kansas Medical Center, we were able to raise the incentive to $50 for each participant for each assessment, for a total of $150 for participating in our study.

We began collecting TEPR data on our participants in August 2019. We hope to provide data on this unique instrument for our Year 3 final report.

Assessment of participants were expanded to include aggregate findings of each participant based on the industry in which they are employed. The information gathered from this type of categorical analysis will allow us to make possible evaluations regarding the impact of these industries on the health and fitness of their employees' ability to drive. Also, this information can be utilized to make future recommendations to improve working conditions such that employees' fitness and performance as drivers can be improved and/or sustained successfully.

References

1. Hege A, Perko M, Johnson A, Yu CH, Sönmez S, Apostolopoulos Y. Surveying the Impact of Work Hours and Schedules on Commercial Motor Vehicle Driver Sleep. Safety and Health at Work. 2015;6(2):104-113.

2. Chen C, Xie Y. Modeling the safety impacts of driving hours and rest breaks on truck drivers considering time-dependent covariates. Journal of safety research. 2014;51(Supplement C):57-63.

3. Mayhew DR, Simpson HM, Wood KM, Lonero L, Clinton KM, Johnson AG. On-road and simulated driving: concurrent and discriminant validation. Journal of safety research. 2011;42(4):267-275.

4. Robb G, Sultana S, Ameratunga S, Jackson R. A systematic review of epidemiological studies investigating risk factors for work-related road traffic crashes and injuries. Injury Prevention. 2008;14(1):51-58.

5. Apostolopoulos Y, Shattell MM, Sonmez S, Strack R, Haldeman L, Jones V. Active living in the trucking sector: Environmental barriers and health promotion strategies. J Phys Activ Health. 2012;9.

6. Apostolopoulos Y, Sonmez S, Shattell M, Belzer MH. Worksite induced morbidities of truck drivers in North America: a research meta-analysis of an underserved population. Am Assoc Occup Health Nurs J. 2010;58.

7. Apostolopoulos Y, Sonmez S, Shattell M, Haldeman L, Stack R, Jones V. Barriers to truck drivers' health eating: environmental Influences and health promotion Strategies. J Workplace Behaviour Health. 2011;26.

8. Lemke MK, Apostolopoulos Y, Hege A, Sönmez S, Wideman L. Understanding the role of sleep quality and sleep duration in commercial driving safety. Accident Analysis & Prevention. 2016;97(Supplement C):79-86.

9. Crizzle AM, Bigelow P, Adams D, Gooderham S, Myers AM, Thiffault P. Health and wellness of long-haul truck and bus drivers: A systematic literature review and directions for future research. Journal of Transport & Health. 2017.

10. Marshall, S.P., 2007. Identifying cognitive state from eye metrics. Aviat Space Environ Med 78(5S), B165-175.