MPC-605
January 29, 2020

Project Title

Validation of Smartphone Alertmeter Fatigue Assessment Device for Transportation Workers

University

University of Denver

Principal Investigators

Patrick Sherry, Ph.D.
Research Professor, NCIT
University of Denver
Phone: (303) 871-2495
Email: patrick.sherry@du.edu
ORCID: 0000-0001-9346-6931

Jesse Owen, Ph.D.
Professor
University of Denver
Phone: (303) 871-2495
Email: jesse.owen@du.edu
ORCID: 0000-0003-2307-9447

Research Needs

Improving transportation safety is the number one strategic goal of the US DOT Specifically, "Reduce Transportation-Related Fatalities and Serious Injuries Across the Transportation System." [1] Fatigue has been thought to be a major factor contributing to accidents. A recent publication from NHSTA estimates that from 2 percent to 20 percent of annual traffic deaths are attributable to driver drowsiness. [2] According to NHTSA, annually on average from 2009 to 2013, there were over 72,000 police-reported crashes involving drowsy drivers, injuring more than an estimated 41,000 people, and killing more than 800, as measured by NHTSA's Fatality Analysis Reporting System (FARS) and National Automotive Sampling System (NASS) General Estimates System (GES). [3] FARS is a census of all fatal crashes that occur on the Nation's roadways. NASS GES contains data from a nationally representative sample of police-reported crashes that result in fatality, injury, or property damage. Using these data bases, one study inferred the existence of additional drowsy-driving crashes by looking for correlations with related factors such as the number of passengers in the vehicle, crash time and day of week, driver sex and crash type. Similarly, another study was conducted by the AAA Foundation for

[1] DOT Strategic Plan. https://www.transportation.gov/dot-strategic-plan (from web August 16, 2018.)
[2] 2015 Lifesavers National Conference on Highway Safety Priorities, Mark R. Rosekind, Ph.D., Administrator, NHTSA (March 16, 2015). Retrieved from www.nhtsa.gov/About+NHTSA/Speeches,+Press+Events+&+Testimonies/remarks-mr-lifesavers-03162015
[3] National Center for Statistics and Analysis. (2011, March). Traffic Safety Fact Crash*Stats: Drowsy Driving. (DOT HS 811 449). Washington, DC: NHTSA. Retrieved from www-nrd.nhtsa.dot.gov/pubs/811449.pdf

Traffic Safety and analyzed data from NHTSA's NASS Crashworthiness Data System (CDS). They estimated that 7 percent of all crashes and 16.5 percent of fatal crashes involved a drowsy driver. This suggests that more than 5,000 people died in drowsy-driving-related motor vehicle crashes across the United States in the study year. [4]

A fatal bus crash in California's Central Valley in August 2016 was caused by a 'severely sleep-deprived driver' and a bus company with an abysmal safety record, according to federal investigators in a report released November 13. Reports describe a severely sleep-deprived driver and a bus company with a poor safety record were causes of the crash that killed four passengers and injured 20 others, including the driver. The NTSB reported the driver had only slept about five hours over the 40 hours preceding the Aug. 2, 2016 crash.[i] The bus, traveling from Los Angeles to Modesto, drifted off the right side of Route 99 and struck a highway signpost that nearly sliced the bus from nose to tail.[ii] Fatigue was also cited as a causal factor in a crash that killed 13 people on Interstate 10 near Palm Springs on Oct. 23, 2016 when a charter bus traveling from a casino plowed into the rear of a big-rig whose driver had fallen asleep during a freeway closure. The truck driver was later charged with 13 counts of vehicular manslaughter with gross negligence.[iii] [iv] According to FMCSA records Autobuses Coordinados vehicles failed eight of 29 federal inspections in just under two years, pushing its out-of-service rate to 38 percent, almost five times greater than the national average of eight percent. These practices, and the presence of fatigued drivers, suggest a failed safety culture that may have contributed to the high levels of fatigued drivers and safety violations.

Similarly, on, January 4, 2017, about 8:18 a.m. eastern standard time, Long Island Rail Road (LIRR) passenger train 2817, consisting of six cars, collided with the platform at the end of track 6 in the Atlantic Terminal in Brooklyn (a borough of New York City, New York). The lead end of the lead car came to rest on top of the concrete platform at the end of the track. As result of this accident, 108 people were injured. Damage was estimated at $5.3 million. The NTSB determined the probable cause of the accident was that the engineer fell asleep due to his chronic fatigue as a result of the engineer's severe undiagnosed obstructive sleep apnea.[5]

More recently, Gottlieb, et. al. (2018) studied the relationship between sleep duration and motor vehicle crashes in a sample of 3201 adults, 222 (6.9%) reported at least one motor vehicle crash during the prior year. Fewer hours of sleep ($p = 0.04$), and self-reported excessive sleepiness ($p < 0.01$) were each significantly associated with crash risk. Severe sleep apnea was associated with a 123% increased crash risk, compared to no sleep apnea. Sleeping 6 hours per night was associated with a 33% increased crash risk, compared to sleeping 7 or 8 hours per night. These associations were present even in those who did not report excessive sleepiness. The population-attributable fraction of motor vehicle crashes was 10% due to sleep apnea and 9% due to sleep duration less than 7 hours. Thus, poor sleep, due to either sleep apnea or insufficient sleep duration is strongly associated with motor vehicle crashes in the general population, independent of self-reported excessive sleepiness.[6]

---

[4] Tefft, B. C. (2012). Prevalence of motor vehicle crashes involving drowsy drivers, United States, 1999-2008. Accident Analysis & Prevention, 45(1): 180-186.

[5] NTSB. 2018. https://ntsb.gov/investigations/AccidentReports/Reports/RAB1802.pdf

[6] Gottlieb, D. J., Ellenbogen, J. M., Bianchi, M. T., & Czeisler, C. A. (2018). Sleep deficiency and motor vehicle crash risk in the general population: a prospective cohort study. *BMC medicine*, *16*(1), 44. doi:10.1186/s12916-018-1025-7.

A meta analytic review of studies designed to investigate the relationship between sleepiness at the wheel and motor vehicle accidents was conducted in 2017. The authors concluded that drivers experiencing sleepiness at the wheel are at an increased risk of motor vehicle accidents.[7]

In the rail industry, the Hours of Service law (HSL), first enacted in 1907 and most recently amended in 2008, controls how many hours train employees, dispatching service employees, and signal employees may work. The statute provides maximum on-duty periods for each group of employees, minimum off-duty periods for train employees and signal employees, and establishes how time on duty is to be calculated. The statute also provides additional limitations on consecutive-days and certain monthly limitations on the activity of train employees.

In the Rail Safety Improvement Act of 2008, FRA received regulatory authority to establish hours of service limitations for train employees providing commuter and intercity rail passenger transportation service and on August 12, 2011, FRA published its final rule providing new limitations for passenger train employees which necessitated the evaluation of work schedules for risk of fatigue.

The problem of human operator fatigue in the rail industry has been well documented in various studies and publications. A report by McGeehan, (2018) indicated that driver fatigue led to two commuter train crashes in the New York area in 2016. According to federal investigators Said. Also, a Long Island Rail Road crash at the at the Atlantic Terminal in Brooklyn, which was also attributed in part to fatigue inured over a 100 People and killed an innocent bystander.

Efforts to identify operators and drivers who might experience fatigue or sleepiness when operating a motor vehicle have been on identifying person who might experience fatigue in the near future as well as monitoring drivers. Technology is under development to assess driver performance, while driving, related to fatigue. However, the need to identify operators fatigue levels and potential for decreased performance due to fatigue *before they begin to operate a vehicle* is of considerable importance as well. Once an individual has begun to operate a vehicle even more risk is encountered. Consequently, several attempts to develop devices to measure fatigue outside of vehicles have been attempted.

The psychomotor vigilance test (PVT) (Dinges & Powel, 1985) is perhaps one of the most widely used standard reaction time performance measure. Originally developed for laboratory studies based on a classic psychophysiological reaction time test, it has been used in several studies including one that looked at the sleepiness and fatigue of truck drivers. The PVT can be administered in a standardized format in which the visual stimulus is presented on a computer monitor and the study participant must then respond to having seen the stimulus. The difference between the onset of the presentation of the stimulus and the response is considered the reaction time. The PVT has been shown to be a valid tool for assessing behavioral alertness and vigilant attention performance in a large number of experimental, clinical, and operational paradigms. Balkin et al. [2004] assessed the utility of a variety of instruments for monitoring sleepiness-related performance decrements and concluded that the PVT "was among the most sensitive to

[7] Bioulac, S., Micoulaud-Franchi, J., Arnaud, M., Sagaspe, P., Moore, N., Salvo, F., Philip, P. (2017). Risk of Motor Vehicle Accidents Related to Sleepiness at the Wheel: A Systematic Review and Meta-Analysis, *Sleep*, Volume 40, Issue 10, October 2017, zsx134, https://doi-org.du.idm.oclc.org/10.1093/sleep/zsx134

sleep restriction, was among the most reliable with no evidence of learning over repeated administrations, and possesses characteristics that make it among the most practical for use in the operational environment."

A review of the existing fatigue detection devices by Dawson (2014) found that none of the current technologies met *all* the proposed regulatory criteria for a legally and scientifically defensible device.[8]

Golz, M., Sommer, D., & Trutschel, U. (2010) evaluated commercially available devices for driver fatigue monitoring with particular focus on the needs of the mining industry. Three video-based devices were selected and used with 14 volunteers in an overnight driving simulation study to test their accuracy. EEG and EOG along with percentage of eye closures (PERCLOS), subjectively rated fatigue on the Karolinska Sleepiness Scale (KSS), and driving performance in terms of standard deviation of lateral position in lane (SDL) were also recorded throughout testing sessions. Regression analysis revealed that PERCLOS was significantly related to higher KSS scores and to SDL. The results suggest that under laboratory conditions current FMT devices are reliable and data averaged across several subjects is utilized, but fail to give a valid prediction of subjective fatigue as well as of driving performance on an individual level.[9]

In one recent study by Lee et. al (2010), forty-eight participants completed the polysomnography and the Multidimensional Fatigue Symptom Inventory-short form (MFSI-sf). After sleep monitoring and psychological assessments, the PVT was administered for 10-minutes. Simple correlations and hierarchical linear regression were used to examine the association between PVT lapse count age, apnea hypopnea index (AHI), fatigue, and PVT reaction time. (Lee, Bardwell, Israel, & Dimsdale, 2010). Results showed that PVT lapse count was significantly associated with MFSI-sf physical fatigue ($r = 0.324$, $p = 0.025$). In hierarchical regression the full model ($R^2 = 0.256$, $p = 0.048$), and higher MFSI-sf physical fatigue ($p= 0.040$) also predicted PVT lapse count. In conclusion, the findings suggest that even after controlling for age, BMI, depression, and apnea severity, that fatigue is associated with the PVT lapse.

In another study, eye movements were measured during vigilance tasks following restricted sleep ($n = 33$ participants) to compare ocular measures to a standard measure of drowsiness (OSLER). Their accuracy was tested for detecting increasing frequencies of behavioral lapses on a different task (psychomotor vigilance task [PVT]). Results indicate that the average duration of eyelid closure and the ratio of the amplitude to velocity of eyelid closure were reliable indicators of frequent errors and detecting ≥ 3 lapses (PVT). The authors concluded, that ocular measures, such as duration of episodes of eye closure are promising real-time indicators of drowsiness. (Wilkinson, et. Al., 2013). Wang (2016) also determined that driver drowsiness detection was significantly determined by a combination of percentage of eyelid closure (PERCLOS), average pupil diameter, standard deviation of lateral position and steering wheel reversals.[10]

---

[8] Dawson, D. (2014) Look before you sleep: Evaluating the use of fatigue detection technologies within a fatigue risk management system for the road transport industry. Sleep Medicine Reviews 18, 2, 2014, 141-152.

[9] Golz, M., Sommer, D., Trutschel, U. et al. Evaluation of fatigue monitoring devices. Somnology (2010) 14: 187. https://doi.org/10.1007/s11818-010-0482-9.

[10] Wang,X., & Xu, C. (2016) Driver drowsiness detection based on non-intrusive metrics considering individual specifics. *Accident Analysis & Prevention*, Volume 95, Part B, 2016, pp. 350-357.

Grant, et. al. (2017) used two versions of the psychomotor vigilance test (PVT) to measure alertness due to sleep loss. Two 3-min versions of the psychomotor vigilance test, one smartphone-based and the other tablet based, were validated against a conventional 10-min laptop based PVT. Sixteen healthy participants (ages 22–40; seven males, nine females) completed a laboratory study, which included a practice and a baseline day, a 38-h total sleep deprivation (TSD) period, and a recovery day, during which they performed the three different versions of the PVT every 3 h. For each version of the PVT, the number of lapses, mean response time (RT), and number of false starts showed statistically significant changes across the sleep deprivation and recovery days. The number of lapses on the laptop was significantly correlated with the numbers of lapses on the smartphone and tablet. The mean RTs were generally faster on the smartphone and tablet than on the laptop. All three versions of the PVT exhibited a time-on-task effect in RTs, modulated by time awake and time of day. False starts were relatively rare on all three PVTs. For the number of lapses, the effect sizes across 38 h of TSD were large for the laptop PVT and medium for the smartphone and tablet PVTs. These results indicate that the 3-min smartphone and tablet PVTs are valid instruments for measuring reduced alertness due to sleep deprivation and restored alertness following recovery sleep.[11]

Brunet (2017) investigated a smartphone app, the s2P, that is fairly similar to the PVT. To establish validity 3-min versions of s2P and the PVT were administered to participants every two hours during a 35-h total sleep deprivation protocol. The results showed that the s2P successfully distinguished between alert and sleepy states in the same individual and showed decreasing performance as sleep loss increased. Thus, the s2P produces results that can distinguish a sleep-deprived from a non-sleep-deprived individual and is also equivalent to the PVT in detecting performance decrements. Moreover, a strong relationship between the s2P and subjective measures of sleepiness, was found similar to findings from other PVT studies (Kaida et al., 2006; Van Dongen et al., 2003).[12]

Price, Moore, Galway, & Linden (2017) attempted to determine whether a smartphone app could be used to assess cognitive functioning in persons who might develop cognitive impairment due to brain injuries. The authors developed a bespoke smartphone app to track daily cognitive performance, in order to assess potential levels of cognitive fatigue. Twenty-one participants with no prior reported brain injuries participated in a two-week study. Three cognitive tests were administered 6 times per day: (1) Spatial Span to measure visuospatial working memory; (2) Psychomotor Vigilance Task (PVT) to measure sustained attention, information processing speed, and reaction time; and (3) a Mental Arithmetic Test to measure cognitive throughput. A smartphone-optimized version of the Mental Fatigue Scale (MFS) self-assessment questionnaire was used as a baseline to assess the validity of the three cognitive tests, as the questionnaire has already been validated in multiple peer-reviewed studies. The PVT showed a positive correlation with the prevalidated MFS $r = 0.342$ ($P<.008$). Scores from the cognitive tests were entered into a regression model and showed that only reaction time in the PVT was a significant predictor of

[11] Grant, D.A., Honn, K.A., Layton, M.E. et al. Behav Res (2017).
[12] Brunet, JF., Dagenais, D., Therrien, M. , Gartenberg, D., and Forest, G. (2017) Validation of sleep-2-peak: A smartphone application that can detect fatigue related changes in reaction times during sleep deprivation. Behavioral Research. (2017) 49: 1460. https://doi.org/10.3758/s13428-016-0802-5

fatigue (P=.016, F=2.682, 95% CI 9.0-84.2). Higher scores on the MFS were related to increases in reaction time during our mobile variant of the PVT.[13]

Jongstra (2018) also attempted to demonstrate that a smartphone app assessing neuro psychological functioning would be feasible for use with people at increased risk of dementia during a 6 months follow-up period. **T**he smartphone-based app iVitality was used to administer neuropsychological tests (Memory-Word, Trail Making, Stroop, Reaction Time, and Letter-N-Back) in healthy adults. Feasibility was tested by studying adherence of all participants to perform smartphone-based cognitive tests. A total of 151 participants (mean age in years=57.3, standard deviation=5.3) used the app with a mean adherence during a 6 month time period of 60% (SD 24.7). Results showed that there was moderate correlation between the first attempt of the smartphone-based test and the conventional Stroop and Trail Making tests with Spearman ρ=.3-.5 (P<.001). Correlations increased for both tests when comparing the conventional test with the mean score of all attempts a participant had made, with the highest correlation with Stroop panel 3 (ρ=.62, P<.001). Performance on the Stroop and the Trail Making tests improved over time suggesting a learning effect, with the other tests remaining stable. Moderate validity for the Stroop and the Trail Making tests compared with conventional neuropsychological tests.[14]

Arsintescu, et. al. (2019) investigated the use of a handheld assessment device to assess fatigue and alertness. Based on the Psychomotor Vigilance Task (PVT) which is considered the gold standard fatigue detection test and is used frequently in fatigue research. Ten participants completed a 5-min PVT (NASA-PVT) on a touchscreen device and a 5-min PVT on the original PVT-192. On the day of the experiment, participants arrived in the lab approximately two hours after their habitual wake time. Participants began a routine protocol under dim lighting, beginning two hours after their habitual wake time. The 5-min PVT-192 and NASA-PVT were taken every two hours for at least 24h. The touchscreen NASA-PVT and original computer monitor PVT-192 were sensitive to extended wakefulness in the same manner. The reaction times were slower and the lapses were higher as time progressed on both NASA-PVT and PVT-192 (p<0.001). In addition, as expected, reaction time decrease significantly after 16h of wakefulness. Performance continued to deteriorate and was at its worst after 24h of wakefulness for both PVTs (p<0.001). Thus, the data suggest that the a handheld touchscreen device NASA-PVT is a valid tool for assessing fatigue in field studies.[15]

As can be seen from the above review, the need for a quick and portable assessment tool, prior to a person beginning operation of a vehicle would be extremely valuable to the safety of the transportation system. The purpose of the present proposed project is to gather data designed to validate the Alert Meter as new and promising measure of fatigue and cognitive impairment. The AlertMeter® is a state-of-the-art electronic vigilance test, wherein the stimulus is presented to the study participant visually. The Alert Meter claims to be able to evaluate the presence of

---

[13] Price E, Moore G, Galway L, Linden M. (2017) Validation of a Smartphone-Based Approach to In Situ Cognitive Fatigue Assessment. JMIR Mhealth Uhealth 2017;5(8):e125. URL: https://mhealth.jmir.org/2017/8/e125 DOI: 10.2196/mhealth.6333 PMID: 28818818 PMCID: 5579321.

[14] Jongstra S, Wijsman LW, Cachucho R, Hoevenaar-Blom MP, Mooijaart SP, Richard E Cognitive Testing in People at Increased Risk of Dementia Using a Smartphone App: The iVitality Proof-of-Principle Study. JMIR Mhealth Uhealth 2017;5(5):e68 URL: https://mhealth.jmir.org/2017/5/e68 DOI: 10.2196/mhealth.6939 PMID: 28546139 PMCID: 5465383

[15] Arsintescu, L., Kato, K.H., Cravalho, P.F., Feick, N.H., Stone, L.S., Flynn-Evans, E.E. (2019). Validation of a touchscreen psychomotor vigilance task, *Accident Analysis & Prevention*, Volume 126, 2019, Pages 173-176, ISSN 0001-4575, https://doi.org/10.1016/j.aap.2017.11.041

fatigue and cognitive functioning in a very brief period of time. Currently, there are very few ultra-brief measures of fatigue/vigilance that have been validated. AlertMeter is able to assess vigilance within 2 min (other assessments can take up to 30 min).

The proposed project will build on previous research to demonstrate the accuracy of a measure of fatigue and alertness in the transportation industry and hopefully lead to a reduction in accidents and injuries.

Research Objectives

The objectives of this project are as follows

1. Conduct a review of current literature on measurement of fatigue and alertness
2. Gather data using smartphone alertness measurement devices from employees of the transportation industry
3. Compare the Alert Meter to other existing measures of fatigue and alertness
4. Writing of report & development of recommendations
5. Conduct workshop to facilitate technology transfer regarding what has been learned
6. Presentations at key conferences
7. Post final report on web site

Research Methods

Data will be collected on a sample of health adults over a period of wakefulness. The project will utilize experimental software from the Alert Meter, as well as PVT, Working Memory standardized self-report instruments and Fitbit to assess sleep and wakefulness. The data will be analyzed using statistical techniques to review and evaluate the correlation between existing measures (i.e. the PVT) and to demonstrate the occurrence of performance decrements with increase wakefulness.

Measures & Data Collection

Perceptual Vigilance Test (PVT): The PVT (Dinges & Powel, 1985) is perhaps one of the most widely used standard reaction time performance measure. It has been used in several studies including one that looked at the sleepiness and fatigue of truck drivers. The PVT can be administered in a standardized format in which the visual stimulus is presented on a computer monitor and the study participant must then respond to having seen the stimulus. The difference between the onset of the presentation of the stimulus and the response is considered the reaction time. The PVT has been shown to be a valid tool for assessing behavioral alertness and vigilant attention performance in a large number of experimental, clinical, and operational paradigms. Balkin et al. [2004] assessed the utility of a variety of instruments for monitoring sleepiness-related performance decrements and concluded that the PVT "was among the most sensitive to sleep restriction, was among the most reliable with no evidence of learning over repeated administrations, and possesses characteristics that make it among the most practical for use in the operational environment."

AlertMeter®: The AlertMeter® is a state of the art electronic vigilance test. The stimulus is presented to the study participant visually. The AlertMeter® will be administered to the study participants at the beginning of the baseline period commencing 3 days before the sleep deprivation period in order to achieve a baseline. During the sleep deprivation part of the study they will be asked to complete the measure on a regular basis (e.g., every 2 hours). The participants will also take the AlertMeter® in the post phase of the study. The AlertMeter® will be administered on two platforms (grid-based platform on a tablet and mobile platform on a smartphone). Both platforms will be tested with and without a memory module in the test.

Working Memory Test Battery (WMTB): According to Frenda & Fenn (2016) sleep deprivation has been linked to slowed reaction times in simple attention tasks, decreased auditory vigilance and visuospatial attention, and impaired verbal working memory. The bulk of the research suggests that sleep is essential for working memory. Working memory (WM) tasks—and in particular, counting span, operation span, and reading span tasks—are widely used measures of WM capacity. Conway, (2004) addressed the reliability and validity of the tasks, as well as optimal administration and scoring procedures. In the present study a battery of Working Memory tasks (WMTB) will be administered to assess changes in working memory following sleep deprivation. A standard set of tasks is suggested by Frenda & Fenn (2016) that can be adapted for this study. Conway (2012) notes "the failure to account for practice effects can have serious implications." Consequently, the battery for the current study will use alternate forms wherever possible. Also, a version of the Digit Span Forward (DSF) and the Digit Span Backwards (DSB) subtests of the WAIS-IV will be modified according to suggestions by Blackburn & Benton (1957) to improve reliability.

Stanford Sleepiness Questionnaire (SSQ): The SSQ is a standard Likert response scale used to assess the study participant's self-assessment of their sleepiness (Hoddes & Dement, 1972). The SSQ is administered using a 9-point scale. Responses provide an assessment of the level of sleepiness experienced by the participant.

Daily Sleep Log (DSL): A daily sleep log is a self-report instrument constructed to provide information on the level of activity, sleep, and work that a person engages in over the course of a two-week period. The study participant enters data into a self-report booklet designed to monitor activity.

Fitbit: A self-contained device consisting of a computer chip and an accelerometer that provides an estimate of various activities and movements engaged in over the course of a specified time period. The Fitbit device can be calibrated to accept reading in 10, 15 or 30 second time intervals. Results of these calibrations are then set to estimate amount of sleep or activity.

Epworth Sleepiness Scale (ESS): The ESS (Johns, 1991) is a self-administered questionnaire with 8 questions. Respondents are asked to rate, on a 4-point scale (0-3), their usual chances of dozing off or falling asleep while engaged in eight different activities. The higher the ESS score, the higher that person's average sleep propensity in daily life (ASP), or their 'daytime sleepiness'. The ES had a statistically significant association with self-rated problem sleepiness. The questionnaire takes no more than 2 or 3 minutes to answer.

Expected Outcomes

The research will identify a new device and technology that can be readily deployed in the operational environment to assess fatigue and alertness of operators and drivers before they being operating vehicles. The technology will hopefully lead to a reduction in drowsy driving, fatigue and an increase in alertness and vigilance. Ultimately, the utilization of the device could lead to a reduction in accidents and injuries in the transportation system.

Relevance to Strategic Goals

This project will contribute to the two of the USDOT Strategic Goals, namely safety and economic competitiveness. The primary goal will be the **safety** of the employees and the public will be enhanced by the development of a technology that can be used to reduce the likelihood of impaired drivers (e.g. as a result of fatigue or sleepiness) operating vehicles. In addition, the secondary goal will be the **economic competitiveness** of the transportation system is also influenced by the improving safe practices and safety culture in that safety is directly tied to the bottom line of a transportation organization. Decreasing accident injuries and fatalities ensures the safe, ethical operation and economically competitive nature of the system.

The proposed study is also relevant to the strategic goals will also contribute to the transportation industry by contributing to the development of an innovative technology that will that Improve the Safety and Performance of the Nation's Transportation System. the project will enhance the existing federal effort by contributing to safety, increasing economic competitiveness and efficiency, developing the work force and contributing to innovation in the transportation system in the US.

Educational Benefits

Several graduate students will assist with the project thereby contributing to the development and education of graduate students who will later be employed in the industry. These students will gain experience in the data collection techniques commonly used in the transportation industry. In addition, they will gain an understanding of the theory and best practices associated with safety and workforce development.

Technology Transfer

In order to facilitate the technology transfer obtained in the present investigation three separate events will be undertaken.

1. Educational briefing for stakeholders in the immediate project held on the site or the premises of the research sites.
2. A workshop on the DU Campus with invitees from local DOT and other community agencies to review and discuss key findings.
3. The development of a video and webinar on the findings to be posted on NCIT web page.

Work Plan

Achieving the overarching goal of this project requires the completion of several different tasks. Since the project will be built upon the previous work and studies we anticipate that the results will be a significant contribution to the existing literature. Permission from participating organizations will be needed to gather data from participants.

Task 1 - Literature Review
Review relevant psychological, operational, and experimental studies and papers to determine the measurement of fatigue and alertness relative to transportation safety.

Task 2 – Data Collection
The alertness measurement devices methods to obtain information on fatigue and alertness during work or simulated work times.

Task 3 – Data Analysis
Data will be analyzed to assess the relationship between the various measures, relative to wakefulness and cognitive performance and reaction time.

Task 4 - Reporting Writing
Draft report will be discussed with stakeholders describing the results of the research and identification of hypothesized linkages.

Task 5 - Stakeholder Feedback
Following the completion of the draft report stakeholders relevant feedback will be integrated into the report.

Task 6 – Tech Transfer Meetings
The draft report will be shared with stakeholders and relevant findings will be disseminated.

	Months						
Task	**1 – 3**		**4 – 6**		**7 - 9**		**10 – 12**
1							
2							
3							
4							
5							
6							

Project Cost

Total Project Costs: $239,194
MPC Funds Requested: $119,597
Matching Funds: $119,597
Source of Matching Funds: Predictive Safety, Inc., in-kind support

References

1. Arsintescu, L., Kato, K.H., Cravalho, P.F., Feick, N.H., Stone, L.S., Flynn-Evans, E.E. (2019). Validation of a touchscreen psychomotor vigilance task, *Accident Analysis & Prevention*, Volume 126, 2019, Pages 173-176, ISSN 0001-4575, https://doi.org/10.1016/j.aap.2017.11.041

2. Bioulac, S., Micoulaud-Franchi, J., Arnaud, M., Sagaspe, P., Moore, N., Salvo, F., Philip, P. (2017). Risk of Motor Vehicle Accidents Related to Sleepiness at the Wheel: A Systematic Review and Meta-Analysis, *Sleep*, Volume 40, Issue 10, October 2017, zsx134, https://doi-org.du.idm.oclc.org/10.1093/sleep/zsx134
3. Brunet, JF., Dagenais, D., Therrien, M., Gartenberg, D., and Forest, G. (2017) Validation of sleep-2-peak: A smartphone application that can detect fatigue related changes in reaction times during sleep deprivation. Behavioral Research. (2017) 49: 1460. https://doi.org/10.3758/s13428-016-0802-5
4. Dawson, D. (2014) Look before you sleep: Evaluating the use of fatigue detection technologies within a fatigue risk management system for the road transport industry. Sleep Medicine Reviews 18, 2, 2014, 141-152.
5. Donovan KA, Jacobsen PB. (2010). The Fatigue Symptom Inventory: a systematic review of its psychometric properties. Support Care Cancer. 2010 Feb;19(2):169-85. DOI: 10.1007/s00520-010-0989-4. Epub 2010 Sep 8.
6. Donovan KA1, Stein KD, Lee M, Leach CR, Ilozumba O, Jacobsen PB. (2015). Systematic review of the multidimensional fatigue symptom inventory-short form. *Support Care Cancer*. 2015 Jan;23(1):191-212. DOI: 10.1007/s00520-014-2389-7. Epub 2014 Aug 22.
7. DOT Strategic Plan. https://www.transportation.gov/dot-strategic-plan (Aug 16, 2018.)
8. Golz, M., Sommer, D., Trutschel, U. et al. Evaluation of fatigue monitoring devices. Somnology (2010) 14: 187. Https://doi.org/10.1007/s11818-010-0482-9.
9. Gottlieb, D. J., Ellenbogen, J. M., Bianchi, M. T., & Czeisler, C. A. (2018). Sleep deficiency and motor vehicle crash risk in the general population: a prospective cohort study. *BMC medicine*, *16*(1), 44. doi:10.1186/s12916-018-1025-7.
10. Grant, D.A., Honn, K.A., Layton, M.E., Riedy, S. M., and Van DOngen, H. P.A. (2017). A 3-minute smartphone-based and tablet-based psychomotor vigilance tests for the assessment of reduced alertness due to sleep deprivation. Behav Res (2017) 49: 1020. https://doi.org/10.3758/s13428-016-0763-8
11. https://www.scpr.org/news/2017/11/13/77705/fatigue-poor-safety-caused-deadly-california-bus-c/
12. Jongstra S, Wijsman LW, Cachucho R, Hoevenaar-Blom MP, Mooijaart SP, Richard E Cognitive Testing in People at Increased Risk of Dementia Using a Smartphone App: The iVitality Proof-of-Principle Study. JMIR Mhealth Uhealth 2017;5(5):e68 URL: https://mhealth.jmir.org/2017/5/e68 DOI: 10.2196/mhealth.6939 PMID: 28546139 PMCID: 5465383
13. Kaida, K., Takahashi, M., Åkerstedt, T., Nakata, A., Otsuka, Y., Haratani, T., & Fukasawa, K. (2006). Validation of the Karolinska sleepiness scale against performance and EEG variables. *Clinical Neurophysiology*, 117, 1574–1581.
14. Lee, I.-S., Bardwell, W. A., Ancoli-Israel, S., & Dimsdale, J. E. (2010). Number of Lapses during the Psychomotor Vigilance Task as an Objective Measure of Fatigue. *Journal of Clinical Sleep Medicine* , 6(2), 163–168.

15. Lifesavers National Conference on Highway Safety Priorities, Mark R. Rosekind, Ph.D., Administrator, NHTSA (March 16, 2015).
16. National Center for Statistics and Analysis. (2011, March). Traffic Safety Fact Crash*Stats: Drowsy Driving. (DOT HS 811 449). Washington, DC: NHTSA. Retrieved from www-nrd.nhtsa.dot.gov/pubs/811449.pdf
17. NTSB. (2017) Motor coach Collision with Combination Vehicle Palm Springs, California https://www.ntsb.gov/news/events/Documents/2017-HWY17MH005-BMG-abstract.pdf
18. NTSB. (2018). Long Island Rail Road Passenger Train Strikes Platform in Atlantic Terminal. https://ntsb.gov/investigations/AccidentReports/Reports/RAB1802.pdf
19. NTSB. Federal Regulator Not Doing Enough to Keep Unsafe Operators Off Roads. https://www.ntsb.gov/news/press-releases/Pages/PR20171113.aspx
20. Price E, Moore G, Galway L, Linden M. (2017) Validation of a Smartphone-Based Approach to In Situ Cognitive Fatigue Assessment. JMIR Mhealth Uhealth 2017;5(8):e125. URL: https://mhealth.jmir.org/2017/8/e125 DOI: 10.2196/mhealth.6333 PMID: 28818818 PMCID: 5579321.
21. Shuyan, M. & Gangtie, L. (2009). Expert Systems With Applications, May 2009, Vol.36(4), pp.7651-7658.
22. Tefft, B. C. (2012). Prevalence of motor vehicle crashes involving drowsy drivers, United States, 1999-2008. Accident Analysis & Prevention, 45(1): 180-186.
23. Van Dongen, H. P. A., Maislin, G., Mullington, J. M., & Dinges, D. F. (2003). The cumulative cost of additional wakefulness: Dose–response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep*, 26, 117–129.
24. Wang,X., & Xu, C. (2016) Driver drowsiness detection based on non-intrusive metrics considering individual specifics. Accident Analysis & Prevention, Volume 95, Part B, 2016, pp. 350-357
25. Wilkinson VE; Jackson ML; Westlake J; Stevens B; Barnes M; Swann P; Rajaratnam SMW; Howard ME. The accuracy of eyelid movement parameters for drowsiness detection. *Journal of Clinical Sleep Medicine*, 2013;9(12):1315-1324.

---

[i] https://www.ntsb.gov/news/press-releases/Pages/PR20171113.aspx
[ii] https://www.ntsb.gov/news/press-releases/Pages/PR20171113.aspx
[iii] https://www.scpr.org/news/2017/11/13/77705/fatigue-poor-safety-caused-deadly-california-bus-c/
[iv] https://www.ntsb.gov/news/events/Documents/2017-HWY17MH005-BMG-abstract.pdf