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Truck Driving Distractions: Impact on Performance and Physiological Response

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Distracted driving is becoming more prevalent as automobile use is commonplace and technology use grows in pervasiveness. The present study investigated the impact of cell phone, touch MP3, and external environmental distractions on commercial truck driving performance. Commercial truck drivers' performance and physiological responses were monitored while they drove a simulated cab through various control and distraction scenarios. The results support previous findings that distractions, particularly the phone and touch MP3, reduce driving performance and increase cognitive resource allocation in truck drivers.

The car is a staple of modern American life. Research has shown that Americans have steadily increased their car travel to the tune of roughly 3 trillion vehicle miles per year in the mid-2000s (Federal Highway Administration, 2011). The cell phone, another ubiquitous item in the lives of many Americans, is on the rise as well. Global mobile data traffic in 2012 grew 70 percent from 2011 levels and the average smart phone in 2017 is expected to generate eight times as much traffic as that of 2012 (Cisco, 2013). With cars and cell phones dominating larger portions of the lives of many and people seeking to accomplish more in less time, growth in distracted driving is not surprising. According to a survey by the Center for Disease Control (2011), nearly seven in ten drivers reported talking on cell phones while driving in the last 30 days. Almost half of drivers have admitted to sending text messages while driving (AT&T, 2013), with the actual percentage likely being higher. This rise in distracted driving has manifested itself on America's roads – almost 20 percent of injury crashes are now related to distraction (National Highway Traffic Safety Administration, 2012).

The fact that cell phone use can distract drivers is fairly intuitive and has been demonstrated through many studies. On a physiological level, driving-related brain activity is reduced by 37 percent for drivers talking on a cell phone (Just, Keller, & Cynkar, 2008). This finding demonstrates that, when distracted, drivers reallocate their limited cognitive resources and attention to non-driving behaviors. As a result, drivers monitor mirrors and instruments less frequently, resort to hard braking more often, and report feeling less safe (Harbluk, Noy, & Eizenman, 2002). Portable music players (e.g. iPod, MP3 player) are also common in-car distractions. Drivers have increased perception response times and collision rates when executing search tasks on a music player (Chisolm, Caird, & Lockhart, 2008), and search tasks also cause drivers to deviate significantly from lane centers (Salvucci, Markley, Zuber, & Brumby, 2007). Like phones, touch MP3 players also require drivers to allocate cognitive resources to non-driving tasks. Distraction and associated danger can also arise from factors out of the driver's control, such as the driving environment. For example, construction work zones create distractions that lead to more fatal crashes and multi-vehicle accidents than non-work zones (Zhao & Garber, 2001). Research shows that possible distractions are everywhere, but distractors that yield the greatest performance detriments have yet to be determined.

The present study investigated the impact of cell phones, touch MP3 players, and external environmental distractions on commercial truck driving performance. Previous investigations of distracted driving primarily used crash data statistics, naturalistic observation, driving simulators, or combinations thereof (Stutts et al., 2005). The present study extends that prior body of driver distraction research in a variety of ways. First, the participant pool consisted of licensed commercial truck drivers (as opposed to non-professional drivers) who are especially at risk for distraction because of the lengths of their journeys. Second, participants operated a realistic driving simulator in a controlled lab-setting to experience manipulated driving conditions and distractions without creating danger on the roads. Finally, electroencephalogram (EEG) and electrocardiogram (ECG) were used to measure physiological responses from participants while they drove through the scenarios, data not available in crash statistics or naturalistic studies. EEG sensors are able to objectively demonstrate changes in cognitive resource allocation, such as rises in frontal theta activity and decreases in parietal alpha activity (Lei & Roetting, 2011), while ECG sensors characterize cognitive resource allocation via heart rate measurements (Reimer & Mehler, 2011). It was hypothesized that cell phones, touch MP3 players, and external environmental distractions would increase the aforementioned resource-related physiological responses and decrease driving performance. This study sought to improve upon analyses of previously-collected commercial truck driving data, which are fraught with under-reporting of distractions by commercial drivers (Stutts et al., 2001) and improve on naturalistic studies that are limited by biased, incomplete, and tampered data from trucking companies.

METHODS

Participants

Twenty-two Commercial Motor Vehicle (CMV) operators (21 males, 1 female) were recruited from several truck companies.

Procedure

After completing a consent form, participants were given a brief demographics survey. Advanced Brain Monitoring's (ABM) X10 EEG and ECG sensors were attached to the participants. The participants were then given a brief tutorial on MP3 player usage; no tutorials were necessary for participants' own cell phones. Once the participant was familiar with the touch MP3, baseline physiological levels were measured with each participant sitting in the truck driving simulator, remaining relaxed and alert for five minutes. The simulator was a truck cab equipped with hydraulic Moog pistons. The pistons, along with the simulation, helped provide realistic environmental noises and responses to g-forces, bumps, and CMV movements. Additionally, the side mirrors were linked to the simulation, which allowed participants to use their mirrors per usual. The simulated highway was projected on three different screens with three CHRISTIE Projectors.

During the experimental sessions, participants completed eight randomized scenarios in which they drove a simulated truck on a 4-mile stretch of highway while being exposed to various distractions. Each scenario was divided into five segments (two with distractions and three without, alternating). During the non-distraction segments, participants drove without encountering any distractions. During the distraction segments, participants were exposed to a cell phone distraction, touch MP3 distraction, external environmental distraction, or a combination of the three. Overall, the participant completed 12 different combinations of distraction segments and one type of non-distraction segment during the 8 scenarios (see Table 1). Scenario 1 contained no distraction segments to serve as the control, while scenarios 2-8 contained cell phone, MP3 player, and external environmental distraction segments, or a combination of the three. Scenarios containing the phone distraction required the participant to make a call and hold a conversation with a research assistant in another room. The conversation topics were initiated by the research assistant and chosen from a bank of questions related to truck driving. Scenarios containing the MP3 player distraction required the participant to listen to embedded instructions (e.g. finding a song by an artist, forwarding to the next track, or identifying the song's designation), adjust the volume of the song that was playing, or identify the current song. During the external environmental distraction scenarios, participants drove through an area of construction (one or both sides of the road) or an area with a car crash on one side of the road. All physiological responses from participants were measured with the attached EEG and ECG sensors to determine cognitive resource allocation in each scenario. Driving performance during each scenario was recorded by the simulator.

RESULTS

One-way repeated measures ANOVAs were conducted to evaluate performance and physiological metrics during the experimental distraction segments with Box's correction applied to correct for violations of sphericity.

Performance Measures

Driving performance was assessed through the driver's total number of driving errors during each segment. Errors included lane deviations, off-road driving, speed violations, random braking occurrences, and collisions. Due to outliers and missing data, 20 out of the 22 participants were used in the following analysis. A significant effect was found for the experimental segments, $F(6.275, 119.219) = 13.601$, $p = .000$, with drivers committing significantly more errors in each of the distraction segments compared to the segment without distractions. The segments requiring listening to the embedded instructions on the touch MP3 resulted in more errors compared to the other distraction types, with the "MP3 + Construction Two Sides" segment displaying the greatest total number of errors. Table 1 outlines the errors committed in each segment.

Segment	Mean	Std. Dev.
No Distraction	2.50	1.49
Phone	3.92*	2.04
MP3	7.75*	3.48
Phone + MP3 Volume Control	4.30*	2.34
Phone + MP3 Song Naming	5.30*	2.88
Construction Two Sides	3.65*	2.03
Car Accident	4.30*	2.84
Phone + Construction One Side	6.45*	2.87
Phone + Car Accident	4.35*	3.01
MP3 + Construction One Side	7.55*	2.74
MP3 + Construction Two Sides	8.50*	3.74
Phone + MP3 Volume Control + Construction Two Sides	5.60*	2.03
Phone + MP3 Song Naming + Construction One Side	7.85*	3.78

Table 1: Mean number of total errors per segment. *=sig. diff. (p<.05) from "No Distraction" segment

Physiological Measures

Researchers collected EEG measures including frontal lobe theta (4-8hz recorded at sensor sites F4, F4, and Fz) and parietal lobe alpha (8-12hz recorded at sensor sites P3, P4, and POz). Due to outliers and missing data, 16 out of the 22 participants were used in the following analysis. A significant effect was found for frontal lobe theta, $F(2.817, 42.259) = 4.138$, p = .013 with drivers in all but three distraction segments experiencing significantly higher levels of frontal lobe theta compared to "No Distraction" segments. Overall, the "Phone + MP3 Song Naming + Construction One Side" segment induced the largest and most significantly different frontal lobe theta levels compared to the other distraction segments (Table 2).

Segment	Mean	Std. Dev.
No Distraction	970.75	2648.02
Phone	4679.66*	4967.13
MP3	4607.18	8776.75
Phone + MP3 Volume Control	6414.61*	6734.44
Phone + MP3 Song Naming	6208.00*	6804.35
Construction Two Sides	2226.96	4971.93
Car Accident	430.98	1932.01
Phone + Construction One Side	4374.29*	4752.53
Phone + Car Accident	4025.88*	3901.17
MP3 + Construction One Side	3189.54*	5268.44
MP3 + Construction Two Sides	3436.69*	6250.98
Phone + MP3 Volume Control + Construction Two Sides	5400.60*	7474.61
Phone + MP3 Song Naming + Construction One Side	6509.14*	9224.96

Table 2: Change from baseline Frontal Lobe Theta values per segment. *=sig. diff. (p<.05) from "No Distraction" segment

A significant effect was found for parietal lobe alpha, $F(2.307, 34.607) = 6.601$, p = .003, with four distraction segments producing higher mean levels of parietal lobe alpha than those from segments with no distractions (Table 3). Overall, the "Phone + MP3 Song Naming" segment induced the largest and most significantly different parietal lobe alpha levels compared to the other distraction segments.

Segment	Mean	Std. Dev.
No Distraction	391.56	1765.00
Phone	1444.16*	1601.64
MP3	1517.05	3084.32
Phone + MP3 Volume Control	2453.14*	2692.56
Phone + MP3 Song Naming	2526.29*	3484.01
Construction Two Sides	159.55	1192.14
Car Accident	-658.75	1038.49
Phone + Construction One Side	937.08	1358.94
Phone + Car Accident	747.82	1126.31
MP3 + Construction One Side	811.37	2088.55
MP3 + Construction Two Sides	420.84	1694.11
Phone + MP3 Volume Control + Construction Two Sides	1233.91	1617.66
Phone + MP3 Song Naming + Construction One Side	1149.47*	1530.60

Table 3: Change from baseline Parietal Lobe Alpha values per segment. *=sig. diff. (p<.05) from "No Distraction" segment

ECG measures including heart rate (HR) and heart rate variability (HRV) were collected during each scenario. Due to outliers and missing data, 17 out of the 22 participants were used in the following ECG analysis. A significant effect for HRV was found, $F(4.801, 76.823) = 2.436$, p = .044, with the "MP3" and "Phone + MP3 Volume Control + Construction Two Sides" segments producing increased HRV in the participants compared to segments with no distractions (Table 5). The "Phone + MP3 Volume Control + Construction Two Sides" segments produced the greatest HRV.

Segment	Mean	Std. Dev.
No Distraction	-12.17	69.12
Phone	23.21	91.89
MP3	29.62*	85.84
Phone + MP3 Volume Control	0.33	82.22
Phone + MP3 Song Naming	12.30	90.91
Construction Two Sides	-2.68	76.47
Car Accident	-19.51	71.31
Phone + Construction One Side	12.99	80.73
Phone + Car Accident	1.93	81.97
MP3 + Construction One Side	14.29	95.75
MP3 + Construction Two Sides	18.59	83.17
Phone + MP3 Volume Control + Construction Two Sides	31.33*	73.78
Phone + MP3 Song Naming + Construction One Side	16.06	80.98

Table 5: Change from baseline Heart Rate Variability values per segment. *=sig. diff. (p<.05) from "No Distraction" segment

No significant effects were found for HR, $F(3.724, 59.577) = 2.120$, $p = .094$.

DISCUSSION

Unlike other studies related to distracted driving, the present study used licensed commercial truck drivers to examine the individual and combined effects of cell phone, touch MP3, and external environmental distractors in a controlled lab setting. Participants completed several realistic driving scenarios that contained visual, auditory, and tactile feedback in a high-fidelity simulator. Furthermore, participants were attached to EEG/ECG sensors that objectively measured their physiological responses. The results indicate that cell phone, touch MP3, and environmental distractions induce decreased driving performance and increased non-driving cognitive resource allocation in truck drivers. More specifically, cell phones and touch MP3 players, used individually as well as together, were shown to impact performance and cognitive resource allocation more than any other driving condition.

According to the driving performance measures, participants in any of the experimental scenarios committed more driving errors than were induced in the control scenario. Drivers reallocated their limited driving-related cognitive resources and attention during the distraction conditions to accommodate for the secondary distraction tasks, which affected primary driving task performance (Posner & Boies, 1971). These results corroborate previous findings that cell phone (Just, Keller, & Cynkar, 2008), MP3 player (Chisolm, Caird, & Lockhart, 2008), and environmental distractions (Zhao & Garber, 2001) can decrease driving performance by diverting attention away from driving-related behaviors.

Not only did the drivers make more driving errors, they were shown to use more cognitive resources when driving distracted, according to EEG and ECG results. Increased EEG frontal theta activity has been linked to increased activation of cognitive resources during effortful task performance (Smith, Gevins, Brown, Karnik, & Du, 2001). In the present study, frontal theta activity was increased during the "Phone", "MP3", and "Environmental" distraction segments, with the combined "Phone + MP3 Song Naming + Construction One Side" segment exhibiting the greatest frontal theta activity values. These findings demonstrate that the two devices (Just, Keller, & Cynkar, 2008), as well as external distractions (Zhao & Garber, 2001), drew cognitive resources away from driving-related behaviors.

Additionally, decreased parietal alpha activity has been linked to increased used of cognitive resources during effortful task performance (Smith et al. 2001). The present study challenges this finding by demonstrating increased EEG parietal alpha activity (compared to the "No Distraction" segments) for drivers in four of the distraction segments. According to existing research, this change in brain activity reflects decreased sensory perception and a need for increased attention to internal processing (Klimesch, Sauseng, & Hanslmayr, 2007). The phone, which is the common thread in each of the four conditions, decreases sensory perception and increases attention allocation to internal processing. When conversing with the experimenter, participants were required to focus on internal cognitive processes (i.e. answering questions) and therefore pay less attention to sensory information coming from the driving environment.

The results diverged somewhat from the literature in terms of HRV. Participants experienced increases in HRV (compared to the "No Distraction" segments) during two distraction segments, a finding not consistent with previous results on HRV and cognitive resource allocation (Hjortskov, Rissen, Blangsted, Fallentin, Lundberg, & Sogaard, 2004). The difference in findings could be explained by methodology: Previous reports used a power spectral density analysis (PSD) to decompose the HRV signal into various frequencies that correspond with parasympathetic or sympathetic activity, while the frequencies were grouped together for this study. Future research should investigate the effects of distractors on the differing HRV frequencies.

In the present study, several of the individual distractors varied across conditions. For example, touch MP3 use in the "Phone + MP3 Song Naming" condition required participants to identify the song that was currently playing, while touch MP3 use in the "Phone + MP3 Volume Control" condition required participants to adjust the volume on the touch MP3 player. As a result, each condition had to be evaluated separately and the impact of each individual distractor is unclear. Future research should control distractor types more consistently across conditions to analyze distractors' individual effects.

Overall, the present results demonstrate that distractions, particularly in-cab distractions, are detrimental to driving performance. Regulations are currently in place for cell phone use and commercial driving, but not for items such as the touch MP3. The performance and physiological results suggest that touch MP3 use diminishes driving-related cognitive resources similar to phone use, and that regulations should be considered for music player devices.

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REFERENCES

AT&T. (2013). *The Facts about Texting while Driving*. Retrieved from http://www.att.com/gen/pressroom?pid =23181

Center for Disease Control. (2011). *Distracted Driving in the United States and Europe*. Retrieved from http://www.cdc.gov/features/dsdistracteddriving/

Cisco. (2013). *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012-2017*. Retrieved from http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/ white_paper_c11-520862.html

Chisholm, S. L., Caird, J. K., & Lockhart, J. (2008). The effects of practice with MP3 players on driving performance. *Accident Analysis & Prevention*, *40*(2), 704-713

Federal Highway Administration. (2011). *Historical Monthly VMT Report*. Retrieved from http://www. fhwa.dot.gov/policyinformation/travel/tvt/history/

Harbluk, J. L., Eisenman, M., & Noy, Y. I. (2002). *The impact of cognitive distraction on driver visual behaviour and vehicle control* (No. TP# 13889 E). Transport Canada.

Hjortskov, N., Rissen, D., Blangsted, A. K., Fallentin, N., Lundberg, U., & Søgaard, K. (2004). The effect of mental stress on heart rate variability and blood pressure during computer work. *European Journal of Applied Physiology*, *92*(1-2), 84-89.

Just, M. A., Keller, T. A., & Cynkar, J. (2008).A decrease in brain activation associated with driving when listening to someone speak. *Brain Research*, *1205*, 70-80.

Klimesch, W., Sauseng, P., & Hanslmayr, S. (2007). EEG alpha oscillations: the inhibition–timing hypothesis. *Brain Research Reviews*, *53*(1), 63-88.

Lei, S., & Roetting, M. (2011). Influence of task combination on EEG spectrum modulation for driver workload estimation. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *53*(2), 168-179.

National Highway Traffic Safety Administration. (2012). *Distracted Driving 2010*. Retrieved from http://www.distraction.gov/download/research-pdf/2010FactSheet.pdf

Posner, M. I., & Boies, S. J. (1971). Components of attention. *Psychological Review*, *78*(5), 391.

Reimer, B., & Mehler, B. (2011). The impact of cognitive workload on physiological arousal in young adult drivers: a field study and simulation validation. *Ergonomics*, *54*(10), 932-942.

Salvucci, D. D., Markley, D., Zuber, M., & Brumby, D. P. (2007, April). iPod distraction: Effects of portable music-player use on driver performance. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 243-250). ACM.

Smith, M. E., Gevins, A., Brown, H., Karnik, A., & Du, R. (2001). Monitoring task loading with multivariate EEG measures during complex forms of human-computer interaction. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *43*(3), 366-380.

Stutts, J.C., Reinfurt, D.W., Staplin, L., & Rodgman, E.A. (2001). The role of driver distraction in traffic crashes. Report prepared for *AAA Foundation for Traffic Safety*, Washington, DC.

Stutts, J., Feaganes, J., Reinfurt, D., Rodgman, E., Hamlett, C., Gish, K., & Staplin, L. (2005). Driver's exposure to distractions in their natural driving environment. *Accident Analysis & Prevention*, *37*(6), 1093-1101.

Zhao, M., & Garber, N. J. (2001). *Crash characteristics at work zones* (No. UVA/29472/CE01/100,). Pennsylvania Transportation Institute, Pennsylvania State University.