Multi-measure Assessment of Internal Distractions on Driver Performance

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ABSTRACT

The primary objective of this effort is to employ a high fidelity simulator for a small pilot study to assess the impact of internal distractions on traffic safety. While all vehicle distractions have the potential to endanger driver, passenger, and bystander safety, distractions internal to the driver (i.e., mindlessness, being lost-in-thought, mind wandering) can be defined as "the decoupling of attention from the task at hand coincident with a shift in focus to internal thought processes." Recent studies estimate that internally-distracted driving is the least understood and most deadly form of distracted driving: 62% of all driving fatality cases involving distractions are "internal." By contrast, the second deadliest source of distraction, cell phone usage, accounts for 12% of fatalities. Internal Distraction is often unintentional, and can last from a split second to numerous minutes, and while driving, has been shown to occur most frequently during low-stimulus drives. Regardless of content, length, or intensity, whenever perception and attention are decoupled, the risk of "looking but not seeing" increases, along with the likelihood of driver error.

Previous research in this area has documented impairments in driver performance while internally distracted, however the reliability with which internal distraction was "induced" in simulation remains a point of contention. Most simulator-based research that has analyzed the topic employs a "straight road, car following" model to induce mind wandering. In this study, we employ a Route Familiarity scenario coupled with an Unusual Uses Task (UUT) to induce a state of internal distraction while driving. Our novel multi-measure assessment includes: self-report, evaluator observation, and simulator performance measurement (e.g., lane position, speed, following distance). Physiological metrics (e.g., facial expression, eye pupil dilation) with on-board cameras are captured for future analysis. Ultimately, the outcomes of this investigation could lead to countermeasures (e.g., vehicle technologies, improved practices in road geometry, signage, targeted training) that mitigate negative driving outcomes resulting from internal distraction.

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INTRODUCTION

Each day in the United States, more than one thousand persons are injured in distracted driver crashes (NHTSA, 2015). All vehicle distractions have the potential to endanger driver, passenger, and bystander safety, and can be either internal or external both to the vehicle AND operator. There are three primary types of distraction: ***visual*** (i.e., taking eyes off the road), ***mechanical*** (i.e., taking hands off the wheel), and ***cognitive*** (i.e., taking mind off the task of driving). Recent studies estimate that internally-distracted driving is the least understood form of distracted driving. Distractions internal to the person (i.e., mindlessness, being lost-in-thought, mind wandering) can be defined as "the decoupling of attention from the task at hand coincident with a shift in focus to internal thought processes" (Smallwood et al., 2003). Epidemiological studies have shown that mind wandering while driving, by decoupling attention from visual and auditory perceptions, can substantially compromise the ability of the driver to incorporate information from the surrounding environment (Galéra et al., 2012). Based on recent data (Erie Insurance, 2013), 62% of all driving fatality cases involving distractions have been attributed to "internal" sources (e.g., inattention).

Here, we perform a small pilot study, using a motion-based simulator, to attain an improved understanding of the various impacts of internal distractions on driver performance. Related past works are leveraged for the current study, while numerous novelties are introduced pertaining to the design of the simulator experiments (intended to "induce" a state of internal distraction), as well as the variety of metrics employed to measure the poorly-understood phenomenon. Our multi-measure assessment includes: self-report, evaluator observation (qualitative), and simulator performance measurement (quantitative) to correlate the other results. Prospective outcomes could lead to driving-related countermeasures and public policy to mitigate negative driving outcomes resulting from internal distraction.

LITERATURE REVIEW

Mind wandering can be described as the interruption of focus on a task by other thoughts unrelated to that task (Smallwood and Schooler, 2006). Adults mind-wander as much as 30–50% of their waking lives (Schooler et al., 2011). The most commonly used method of measuring mind wandering, Experience Sampling, which involves periodically interrupting individuals during a task and querying the extent to which their attention was on-task (or otherwise) (Smallwood et al., 2004; Smallwood and Schooler, 2015). Experience Sampling techniques include the Sustained Attention to Response Task (SART) (Robertson et al., 1997), which is similar to a standard vigilance task wherein the participant is repeatedly prompted for a target. In addition, self-report questionnaires can be used to measure the occurrence of task-unrelated thought following the completion of a task (Matthews, et al., 1999); one example is the recently established Mind Wandering Questionnaire (MWQ) (Mrazek et al., 2013). These methods of measuring internal distraction have been used in many disciplines, and most recently to study the effects of internal distractions on driving performance and safety.

He et al. (2011) created a "car-following" task in a driving simulator, and participants were subjected to such Experience Sampling. In general, participants showed few deficits in vehicle control, but tended to focus visual attention narrowly on the road ahead (while mind wandering). Yanko and Spalek (2012) employed a simulator where participants followed a car along an unoccupied highway (i.e., a low stimulus driving environment). At random times during the drive, the lead vehicle stopped abruptly requiring a braking response from the participants. The same researchers also hypothesized that as a route becomes more familiar, less effort is required for the driving task, thus increasing the occurrence of mind wandering. Martens and Brouwer (2013) employed a simulator to subject participants to: a) a control case, b) an Internal Driver Distraction (i.e., a reasoning task), and c) an external cognitive distraction (i.e., a listening/remembering task). Finally, Bencich et al. (2014) found self-reported mind wandering was pervasive during daily driving, and simulator mind wandering states were found to affect driving performance. It is important to note the inherent difficulty of measuring mind wandering and the significant limitation of Experience Sampling as a method of measuring an internal state. Smallwood and Schooler (2015) note that states of internal distraction are "fundamentally internal, with few external manifestations," and are thus difficult to objectively measure, relying on reporting from the individual. Experience Sampling allows the experimenter to measure mind wandering at the moment most proximal to its actual occurrence, but inherently -- disrupts or alters the internal state of mind wandering (Smallwood and Schooler, 2015). Such limitations can be overcome if they are supported by other objective measures (Smallwood and Schooler, 2015), an example of which could be driving performance.

In the current study, we investigate internally distracted driving with a high-fidelity simulator. For our counterbalanced cohort, our novel multi-measure assessment includes self-report (e.g., the MWQ), live evaluator-observation, and direct quantitative performance measurement by the simulator itself. Like most simulator studies that were identified, we employ a "car following" driving excursion in the simulator. This task requires constant vigilance on behalf of the driver to maintain their distance from the lead vehicle, and thus allows some experimental control to measure differences in driving performance. Inspired by the route familiarity hypothesis suggested by Yanko, we created a "drive-around-the block" scenario, repeated twice, representing a low-stimulus driving environment conducive to allowing the mind to wander. We attempted to create a state of "internal distraction" using a novel technique that allowed a comparison of a control case driving excursion to a "distraction" driving excursion, "induced" using the "Unusual Uses Task (UUT)" explained in a forthcoming section. The next section describes the research facilities that were leveraged for the current work.

RESEARCH FACILITIES (Driving Simulator)

The research described here was performed within a 6-DOF motion-based simulator that includes a 2-seater passenger cabin with a steering wheel (900^o rotation, force-feedback), pressure-modulated floor pedals (accelerator, brake), and an instrument cluster for driver feedback (e.g., speed, RPM, turn signal indicators). The visualization system is a 360^o theater, 16' diameter by 6' high "ring screen." The screen is front-projected by six projectors (with edge-blending and image warping) to create a single "continuous" wraparound scene. The overall display resolution is 8192 pixels (in circumference) by 768 pixels (in height). The simulator is outfitted with a 2.1 stereo sound system, and is driven by a single tower PC workstation, which features dual-core 2.16 GHz processors, 12 GB Memory, and a 3-output channel, OpenGL-compliant high fidelity graphics processor. Refer to Figures 1-3 for associated hardware imagery. In the next section, we describe the experiments that were designed and conducted specifically for this effort.

Figure 1. Visual System

Figure 2. Motion System

Figure 3. Driver Controls

EXPERIMENT DESCRIPTION

Once screened for eligibility, participants were invited to the Simulation Laboratory for informed consent to perform the experiment. Following informed consent, participants were asked to complete various questionnaires in advance of driving the simulator. These include the following:

- The Adult Attention-Deficit and Hyperactivity Disorder (ADHD) Self-Report scale (ASRS-V1.1) (Kessler et al., 2005),
- The Jerome Driving Questionnaire (Jerome and Segal, 2009), a visual analog scale that provides self-report and collateral data related to driving history and style (e.g., attention, impulsivity, alertness),
- The Mind Wandering Questionnaire (MWQ), to assess trait levels of task-unrelated thought,
- The Driver Behavior Questionnaire (DBQ) (Parker et al., 1995), which investigates a three-fold typology of negative driving behaviors (lapses, errors, and violations).

Participants were briefed on basic simulator safe operation and emergency procedures, and then are asked to complete a 5-minute "acclimation" drive. During the acclimation drive, participants were asked to drive wherever they wish to become familiar with the simulator driving components (e.g., steering wheel and pedals), the virtual driving environment, as well as the motion generated by the simulator. A five-minute break followed the acclimation drive. In an effort to minimize practice effects, the remainder of the study was a crossover design format, and the sequence of the two experimental drives was counterbalanced between participants. Refer to Figure 4.

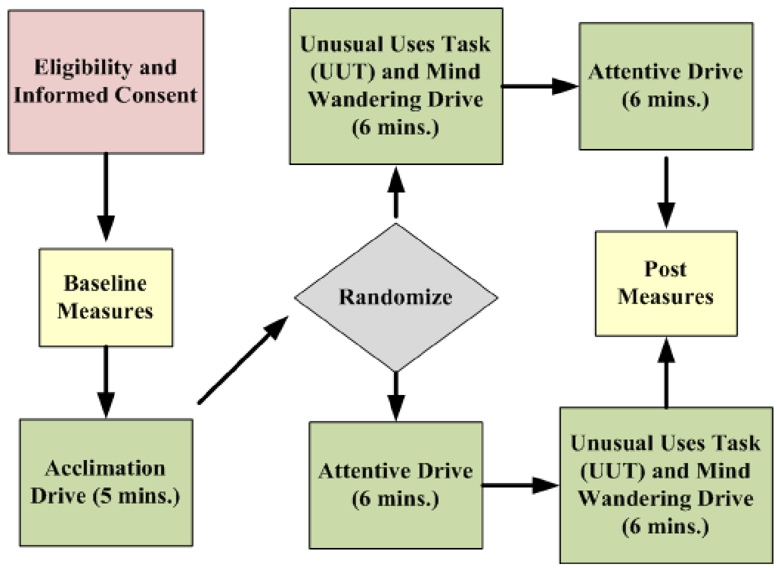

Figure 4. Experimental Design Flowchart

The simulator excursions implemented a simple "car following" task while traveling a common clockwise excursion around the block, twice, in an effort to breed Route Familiarity. The lead vehicle was driven by one of the authors employing safe driving practices, and recorded (and replayed) for each study participant. The excursion had speed limits varying between 30 and 35 mph. All other external stimuli (e.g., traffic vehicles, roadway hazards) that demand added attention and multi-tasking were eliminated. The total length of the excursions was approximately 12,500 feet (~2.5 miles), and each participant was given 6 minutes for each drive. Refer to Figure 5, which shows a diagram of our "Attentive Drive" route, and Figure 6, which displays driver point-of-view at the start of the excursion.

Figure 5. Attentive / Mind wandering Drive (map)

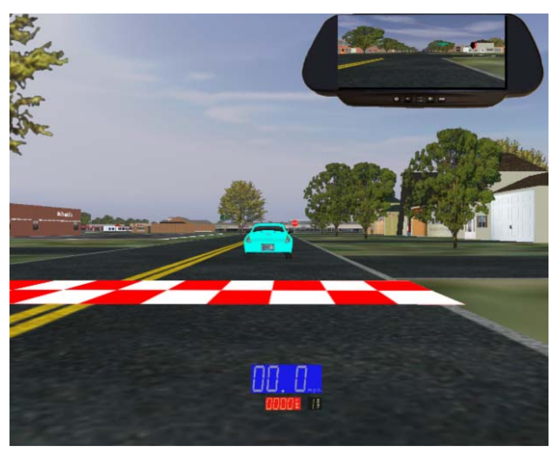

Figure 6. Driver-view of simulator excursion

During the “Attentive Drive” experimental condition, participants were asked to drive a guided course, with instructions solely to “be attentive” and drive to the best of their ability (i.e., remain in their lane, abide by the speed limit, obey traffic signs). Participants were told that they would earn a bonus based on their driving performance -- up to $10). After the Attentive Drive, each participant was given a ten-minute break. Next, during the “Mind-Wandering Drive,” participants were initially told that following the excursion, they will be asked to generate a list of as many uses for a common item as they can (e.g., for this experiment, we used “a ping-pong ball” as our chosen item). This task, known as the Unusual Uses Task (UUT; Guilford, 1967), is a measure of creativity intellect, but has also been shown to help facilitate a state of mind-wandering (Baird, et al., 2012). Participants were told that they would receive a bonus (of up to $10) should they come up with “the most creative uses” for the common item, as an effort to facilitate compliance with the UUT during the drive. Following the drive, participants were given a sheet of paper and one minute to record all their solutions for the UUT acquired during the “Mind wandering” drive. All participants actually received the full bonus, and this deception was revealed at the debriefing following the completion of all study components.

During all drives, the simulator was programmed to collect quantitative data (e.g., speed behavior, behavior at stop signs, and lane maintenance). As a mechanism to maintain the human evaluator in the loop, we likewise created a nine item, 5-point Likert driving performance (Evaluator) scale during the experimental drives, which also included a small section for comments. Upon completion of both drives, each participant was asked to complete the Motion Sickness Assessment Questionnaire (MSAQ) (Gianaros et al., 2010) as a metric for any adverse effects from the simulator environment. Lastly, each participant completed a ten item, 5-point Likert-style questionnaire to describe if and how the UUT impacted various aspects of driving performance. This “Task Engagement” scale was created in-house. In the next section, we describe the essential details of our Pilot Study cohort.

PILOT STUDY COHORT

Our cohort is summarized in Table 1. Included here is basic demographic information, as well as numerous critical elements from the Jerome Driving Questionnaire. This information provides us with a snapshot of how experienced our driving cohort is, and provides some indication of driver safety based on self-reported driving history.

Table 1. Mind Wandering Pilot Study Cohort	
Cohort Size	N=16 (Male: 8 ; Female: 8)
Average Age: Mean (SD)	32.7 (14.4)
Average Years Driving Experience: Mean (SD)	15.9 (14.2)
Average CITY Miles driven (in past month) : Mean (SD)	193.1 (184.3)
Average HIGHWAY Miles driven (in past month) : Mean (SD)	431.8 (637.2)
Number of lifetime vehicle collisions (as a driver)	None: 8 (50%), One: 3 (18.8%) More than one: 5 (31.3%)
Number of speeding tickets (*N=15 responses*)	None: 9 (60%), One: 2 (13.3%) More than one: 4 (26.7%)
Number of tickets for failing to stop (at traffic signal or stop sign)	None: 12 (75%), One: 4 (25%)

<u>Inclusion and Exclusion criteria</u>

Participants are eligible if over 18 years of age, licensed drivers who are actively driving, and not made uncomfortable by the environment of simulators (e.g., claustrophobia, fear due to darkness). Due to their proneness for Morning Sickness, pregnant women are excluded. All participants are screened for physical conditions that would prevent participation in the study, including: epilepsy, past episodes with seizures, and/or proneness to extreme motion sickness (e.g., air, car, or sea). The screening was performed verbally and by way of telephone survey. The research study was pre-approved for full compliance by the Internal Review Board (IRB) at the University at Buffalo.

<u>Recruitment and Compensation</u>

Candidate participants are recruited by way of printed fliers that were posted on bulletin boards at the University at Buffalo. All participants are awarded a $20 gift card at the completion of the experiment. Participants are also told that they will receive a bonus ranging from $0-20 based on their task performances during the Baseline and UUT drives. In actuality, all participants received the full $20 "bonus," but are told otherwise (in advance of their effort) to motivate them to participate, to the best of their ability, in the driving tasks.

RESULTS AND DISCUSSION

As a means to convey the experimental results, we investigate the three major categories (i.e., simulator data (quantitative), self-report/survey data, and evaluator data (qualitative)) separately, while concurrently looking for correlates. At the conclusion of this section, we likewise report data pertaining to simulator sickness (i.e., the MSAQ).

Simulator Data

The driving simulator was programmed to output a variety of performance data during both the Baseline and UUT drives, including excursion speed (m.p.h.), distance to lead vehicle (feet, between vehicle centers), and lateral lane position from vehicle center to lane center (feet), which provides some indication of "swerving" behavior. Refer to Table 2, which reports Max/Avg. Speed and Lane Swerving, and Min/Max/Avg. distance to the lead vehicle (LD), while comparing Baseline (B) to UUT (U) drive conditions. For most drive measures, there was no statistically significant difference between Baseline and UUT drives. Maximum and Average travel speeds are slightly higher for the UUT excursions, however, lane swerving behavior (both Max and Avg.) was nearly identical for the two drive states. Maximum and average lead distances decreased from the Baseline to the UUT drive but was not significant.

Most compellingly, the minimum distance to the lead vehicle decreased during the distracted drive compared to the Baseline drive (i.e., they encroached more on the lead driver during their UUT drive) and this result was significant; $F(1,15)=5.57$, $p=<.05$*. This finding confirms what was observed during the experiments: most participants demonstrated reduced vigilance during the UUT drive likely due to being distracted. There are numerous instances the driver would come "uncomfortably close" to the lead vehicle (e.g., tailgating or near rear-end collision). Several individuals noted that they found it difficult to control their speed and braked harder when approaching the lead vehicle at the stop sign, due to being distracted during the UUT drives. Interestingly, those individuals that reported more creative response to the UUT task (and are likely more distracted) also got even closer to the lead vehicle (see UUT section, below).

Table 2. Cohort Averaged Simulator Measures (Quantitative)

Measure	Mean (B)	Mean (U)	Std. Dev. (B)	Std. Dev. (U)	*p*-value
Speed Max:	38.71	39.52	4.87	5.25	0.253
Speed Avg:	22.79	22.91	1.79	2.20	0.702
LD Min:	***46.92***	***41.09***	***15.95***	***13.60***	***0.032****
LD Max:	773.32	675.21	507.27	443.34	0.371
LD Avg:	358.20	319.66	260.23	272.96	0.403
Swerve Max:	5.01	4.99	1.48	1.63	0.916
Swerve Avg:	2.37	2.41	0.84	0.94	0.671

**Data were highly skewed and transformed to produce normality using a Reflect and Square Root transformation (Tabachnick and Fidell, 1996). A Repeated Measures ANOVA was then conducted to determine differences in minimum distance from the lead driver in UUT drive compared to Baseline.*

Self-Report/Survey Data

A number of surveys are administered, pre and post-experiment, to learn more about individual driver predispositions to internal distraction or mind-wandering behavior.

Mind Wandering Questionnaire*:* The recently established MWQ rates a series of five expert-rated questions on a 6-point Likert scale. The Results (means, and standard deviation) are displayed in Figure 7. As shown, with some variance, mean results can be considered "moderate" for all five questions. This provides some indication that our cohort has some defined propensity for the cognitive tendencies we are attempting to safely induce in this program.

Task Engagement Questionnaire: Likewise, a questionnaire pertaining specifically to the engagement in the UUT task and participant perceived driving effects was issued post-experiment. A total of ten 5-point Likert questions are issued: five of a more general nature, and five pertaining specifically to driving skills (while brainstorming the UUT). Refer to Figure 8. Numerous items in this chart are noteworthy: most participants used the available time to brainstorm UUT (#2); UUT did impact overall driving ability (#5 and #6); most interestingly, drivers reported that UUT had the most impact on speed, and a lesser impact on lane position (#7-8). These self-report findings seem to correspond with what the simulator recorded during actual driving performance (i.e., Table 2), although not necessarily with statistical significance. Lastly, most drivers indicated that they could drive safely while UUT (#10), which seems somewhat counterintuitive but not contradictory to what is known about self-assessment and reporting tendencies.

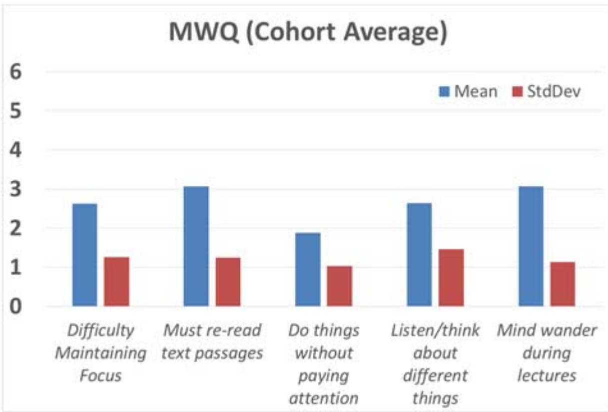

Figure 7. MWQ (Cohort average)

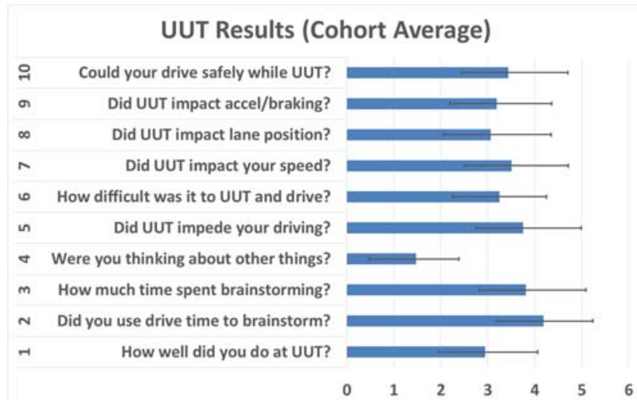

Figure 8. UUT (Cohort average)

Unusual Uses Task Responses: Immediately post-the UUT drive, participants are given 60 seconds to brainstorm a list of unusual uses for a ping pong ball. On average, participants came up with 6.13 (±2.4) responses in that time frame, with a cohort maximum of 10 responses (2 participants, and a cohort minimum of 2 responses (1 participant). Responses ranged from safe ("Beer pong"), to common ("use as a cat toy"), to quirky ("a home for a spider"), to pleasingly creative and unusual ("soft ends for a chair," "a mold for ice cubes," "a paint holder," "eye goggles for tanning," "create a raft from many tied together.") "Creativity" scoring for the UUT included giving one point for each unique response (defined as a response that represented 5% or less of the total responses) normalized by the total number of responses offered by each participant (Guilford, 1967).

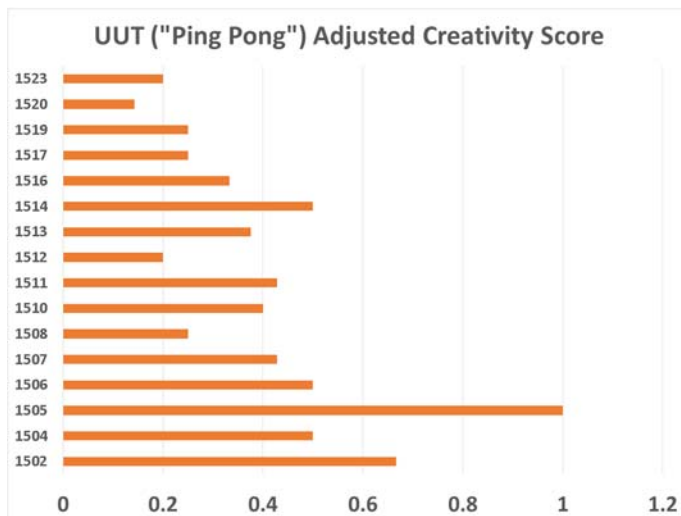

Figure 9. UUT response statistics

Figure 9 demonstrates the adjusted creativity score by participant. This score was negatively correlated to the minimum lead distance during their UUT drive, meaning the more creative responses the participant gave, the closer they tended to drive behind the lead car in front of them ($r(14) = -.51$, $p < .05$). This corroborates our significant earlier finding (Table 2) regarding driving performance decrements.

Adult ADHD Self-report scale (ASRS v1.1):

We investigated to see if there was any correlation between self-reported ADHD (18 questions over two Parts, each on a 5-point Likert scale) and driver performance relative to the Baseline and UUT drives. Within our cohort of 16 drivers, two participants self-reported symptoms that are "highly consistent" with Adult ADHD. The results of decomposing these two participants (1504 and 1506) into a separate cohort, and then comparing their performance results to the remaining cohort of 14 are shown in Table 3. First, note that maximum (and average) speeds are higher for the ADHD cohort (42.0 vs. 38.25 mph for the Baseline drives) than for the non-ADHD cohort. Within the ADHD cohort, maximum speeds are considerably higher for the UUT drive (45.80 mph) when compared to Baseline (42.0

mph), whereas they are relatively stable within the non-ADHD cohort (38.25 mph Baseline, vs. 38.62 mph, UUT). Second, note that swerving behavior for the ADHD cohort is considerably larger than that for the non-ADHD cohort (5.95 ft. vs. 4.87 feet, maximum swerve, Baseline drive). However, when comparing Baseline to UUT drives within cohorts, there is almost no effect for the non-ADHD drivers, whereas swerving behavior actually goes down slightly for the ADHD cohort (5.95 vs. 5.81 feet). Lastly, and most critically, note that minimum distance to the lead vehicle is seen to be MUCH lower for the ADHD cohort than the non-ADHD cohort (32.35 vs. 49.00 mph, Baseline drive), and that the reduction in distance, within cohorts, between Baseline and UUT drives is considerably more dramatic within the ADHD cohort (32.35 to 21.34 mph, (34.0%) ADHD, vs. 49.00 to 43.91 mph, (10.3%) non-ADHD). This data supports earlier evidence and assertions that drivers become less vigilant when they are cognitively distracted by the UUT task, and in their distracted state, tended to follow the lead vehicle much more closely.

Table 3. Cohort breakdown based on ADHD self-report

Measure	Mean - ADHD	Std. Dev. - ADHD	Mean - non-ADHD	Std. Dev. - non-ADHD
Speed Max: B (U)	42.00 (45.80)	3.67 (3.67)	38.25 (38.62)	4.94 (4.89)
Speed Avg: B (U)	23.95 (23.80)	0.07 (0.00)	22.62 (22.78)	1.86 (2.33)
LD Min: B (U)	32.35 (21.34)	22.10 (8.35)	49.00 (43.91)	14.79 (11.81)
LD Max: B (U)	359.18 (411.50)	9.74 (25.95)	832.48 (712.89)	516.48 (463.16)
LD Avg: B (U)	162.95 (182.44)	15.60 (10.13)	386.09 (339.26)	267.24 (287.49)
Swerve Max: B (U)	5.95 (5.81)	0.66 (0.36)	4.87 (4.87)	1.53 (1.72)
Swerve Avg: B (U)	3.05 (3.46)	0.20 (0.51)	2.28 (2.26)	0.85 (0.90)

Evaluator Data

During the experiments, the simulator operator documented driver performance for both the "Baseline" and "UUT" drives in nine categories on a 5-point ("1" = low, 5 = high") Likert scale. Refer to Table 4, which reports the per-category averages for the entire experimental cohort. The first two columns in the Table provide the overall cohort averages (and standard deviations) for the "Baseline" (undistracted) and UUT (distracted) drives. Note that in general, cohort averages are higher for the Baseline drive than for the UUT drive. The only exception is the "Not too slow" category, for which average scores are slightly higher for the UUT drives. Recall that the experiments are counterbalanced. For all 16 participants, a 5-minute acclimation drive was offered first. Then, for 8 of the 16, the "Baseline" drive came next (B1), followed by "UUT" (U2). For the remaining 8/16, it was "UUT" first (U1), followed by "Baseline" (B2). Not surprisingly, scores are generally higher for Baseline followed by UUT (i.e., comparing B1 to U2); five category scores decreased, three increased, and one remained the same. More compelling, perhaps, is the next half of the cohort, for which the UUT drive came first, followed by the Baseline drive (i.e., comparing U1 to B2). In these scenarios, eight category scores increased, and one remained the same. These results are not surprising for two reasons: a) participants are the most acclimated to the simulator for this drive, and more importantly, b) participants are not distracted on this excursion. Finally, we compare Baseline to Baseline (B1 to B2) and UUT to UUT (U1 to U2). As expected, the Baseline-2 drivers scored higher (than Baseline-1 drivers) in five categories, lower in three categories, and equal in one category. Likewise, the UUT-2 drivers scored higher (than UUT-1 drivers) in six categories, lower in two categories, and equal in one category.

Table 4. Evaluator Performance Scores (Per-category averages)

Category	Baseline	UUT	B1	B2	B-delta (B2-B1)	U2	U1	U-delta (U2-U1)
Acceleration	4.56 (0.73)	3.88 (0.89)	4.75	4.38	-0.375	4.38	3.38	1.000
Deceleration	3.69 (0.87)	2.69 (0.95)	3.50	3.88	0.375	2.75	2.63	0.125
Steady Speed	4.50 (0.73)	4.00 (0.97)	4.50	4.50	0.000	4.38	3.63	0.750
No excessive speed	4.13 (0.89)	3.63 (1.02)	4.00	4.25	0.250	3.75	3.50	0.250
Not too slow	4.00 (1.03)	4.06 (1.12)	3.75	4.25	0.500	4.00	4.13	-0.125
Complete Stops	3.94 (1.18)	3.81 (1.33)	4.00	3.88	-0.125	4.00	3.63	0.375
Lateral position	3.69 (0.70)	3.50 (0.97)	3.25	4.13	0.875	3.50	3.50	0.000
Following distance	3.81 (1.05)	3.56 (1.09)	3.38	4.25	0.875	3.88	3.25	0.625
Turn signal usage	4.81 (0.40)	4.56 (0.51)	4.88	4.75	-0.125	4.38	4.75	-0.375

Simulator Sickness (MSAQ)

In addition to the 16 participants who completed the experiment, we had two dropouts due to (pending) simulator sickness. All 16 participants completed the MSAQ, which surveys 16 questions on a 0-9-point Likert Scale for sickness symptoms in four primary categories (e.g., gastrointestinal, sopite). See Figure 10. In general, sickness symptoms are present, but minor, for all participants. Maximum values for each question ranged from 1 to 8 (cohort avg: 4.25), while Mean scores for these categories ranged between 0 and 2 (cohort avg: 0.81). The three most common symptoms (by cohort avg.) are: #5 (I felt queasy), #1 (Sick to stomach), and #11 (I felt nauseated).

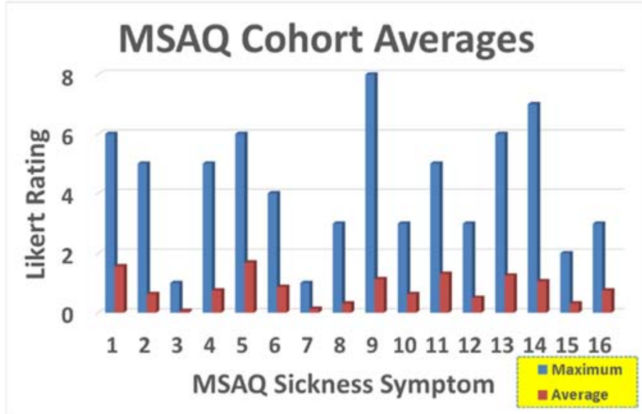

Figure 10. MSAQ Data (cohort average)

SUMMARY AND CONCLUSIONS

All vehicle distractions have the potential to endanger driver, passenger, and bystander safety, and there are three primary types of distraction: ***visual***, ***mechanical***, and ***cognitive***. Driving distractions can be either external or internal to the operator. Based on data from a recent insurance report, a disproportionately large percentage of all distracted driving fatalities have been attributed to "internal" sources (e.g., general distraction or inattention).

For these reasons, leveraging a high-fidelity driving simulator, we performed a small pilot study in an effort to attain an improved understanding of the various impacts of internal distractions on driver performance. We employed a "car following" task that employed a novel "twice around" drive around the block. This strategy leveraged Yanko's assertion that route familiarity breeds a state of mindlessness. Likewise, our method of induction was novel to the field, as we employed an "unusual uses task" (UUT) to distract drivers into thinking beyond the numerous visual, manual, and cognitive skills that are required to safely operate a (simulated) motor vehicle.

Our unique multi-measure assessment included: self-report and survey data, evaluator observation (qualitative), and simulator performance measurement (quantitative) data. Numerous highlights from the data analysis are offered here:

- Simulator data showed little differences in speed and lane swerving data between Baseline and UUT. However, minimum lead distance was found to be lower for UUT drivers (with some significance). This could be indicative of reduced vigilance with driving under distraction.
- The MWQ provided some indication that our cohort, taken as a whole, had a "moderate" predisposition towards internal distraction. Cohort averaged responses on the UUT task-engagement showed that many did feel that the UUT distraction negatively impacted driving performance.
- Taking into consideration the actual responses on the UUT ("ping pong ball") survey, there was negative correlation to the minimum lead distance during their UUT drive, meaning the more creative responses the participant gave, the closer they tended to drive behind the lead car in front of them
- Based on self-report, two drivers among our cohort of 16 were found to have symptoms indicating adult ADHD. When we separated their data from the remainder of the cohort, drive speeds were faster, lateral swerving was more pronounced, and minimum distance to the lead vehicle was much shorter, and even more pronounced when comparing Baseline to UUT drives.
- Experiment evaluators rated driver performance in nine categories on a 5-point Likert scale. Drivers who acclimated first, then drove the UUT, then drove the Baseline drive were observed to show the most pronounced improvement. This was somewhat expected, as drivers were most acclimated for the final drive, and the final drive served as their undistracted (Baseline) drive.
- Simulator sickness was found to be "mild" for the cohort taken as a whole, although most drivers did exhibit some adverse effects. Two persons had to drop out of the study due to perceived symptoms.

The prospective outcomes of this analysis could ultimately result in driving-related countermeasures to mitigate negative driving outcomes from internal distraction. In the next section, we provide an overview of our future work, as well as a number of broader implications of the current research that extend beyond civilian driving applications.

BROADER IMPACTS AND FUTURE WORK

In this first Phase of the project, our team has focused on the challenging problem of attempting to INDUCE a state of mindlessness during the driving task, followed by a novel multi-faceted assessment to MEASURE the resulting degradation in driver performance. A logical second Phase of this endeavor would be to design, develop, implement, and analyze the impact of countermeasures for mind wandering. Examples might include alterations to roadway geometry (e.g., roadway billboards with strategic placement and content), improved driver education and associated public policy (e.g., include mindfulness training as a required component), and multi-sensory cues (e.g., visual, aural, and/or haptic) within the cabin of the vehicle. Such technologies would be prototyped, analyzed, and refined within a simulator environment.

The results presented in this paper could have implications beyond distracted driving. A recent survey (Purcell et al., 2012) revealed that 87% of teachers feel that modern technologies are resulting in “an easily distracted generation with short attention spans.” One modern-day example is “Distracted Walking” - approximately 25% of New York City pedestrians are distracted by a mobile device or headphones while crossing the street (Engel, 2014). Another related topic of civilian and military interest is drowsiness and sleep deprivation. According to the NSF’s “Sleep in America” poll (NSF, 2014), 60% of adult drivers say they have driven a vehicle while drowsy in the past year. In commercial aviation, the same poll found that 25% of pilots claimed that being sleepy has an impact on their job performance “at least once a week,” and about 20% say they have “made a serious error” because of sleepiness. As was demonstrated in the current work, transportation-based M&S can be employed to empirically examine cause and effect analyses for all distractor classifications (cognitive, visual, and mechanical) that could result in desirable countermeasures. These could have critical implications for traffic safety, design and manufacturing (as it pertains to in-vehicle technology), and future legislation and public policy.

The present data analysis could be expanded in size and scope. For example, it might be informative to introduce additional covariates into the data analysis, including the individual results from the MWQ (which were reported simply as a cohort average in Figure 7), and those with self-reported Adult ADHD tendencies (whose extracted averages were compared to the non-ADHD cohort averages in Table 3). Basic cohort-averaged statistics were reported for the Evaluator Likert scores (refer to Table 4), and those metrics would benefit from more formal significance testing relative to the other major classes of results that were reported here (i.e., self-report, quantitative).

Lastly, it is worth mentioning that camera data was collected, and could serve as a critical subcomponent with future implications for this pilot study. Two separate cameras recorded data during the experiment: a “dash camera” that displayed driver point-of-view imagery (i.e., what the driving participant sees), and a “driver cam” that recorded the features of the driver face in high resolution. It was hoped to incorporate this data for the present analysis, however these observations will await future observation. Our ultimate aspiration is to use this data to match certain physiological metrics (e.g., nuances in facial expression, eye pupil dilation, eye blink rate) captured by the facial camera to corresponding driving performance metrics detected by the P.O.V. camera. This data would make a compelling supplement to the diverse set of measures already present in this paper.

ACKNOWLEDGEMENTS

The authors wish to thank the Erie Insurance Group, who researched and disseminated a compelling public health study (and infographic) that served as a critical motivating factor for the current work. Dr. Hulme wishes to acknowledge the ongoing technical and financial support of Moog, Inc., as well as the technical contributions of Dr. Edward Kasprzak from Milliken Research Associates.

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