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BEHAVIORAL EFFECTS OF DRIVER DISTRACTION AND ALCOHOL IMPAIRMENT

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There remains some debate regarding secondary task distractions, such as cell phones, as a risk factor in traffic crashes and their relative risk compared to existing factors, such as engagement in common in-vehicle tasks and alcohol impairment. Moreover, studies of driver impairment often investigate single risk factors rather than combined factors (e.g. distraction task while drunk). This study compared non-distracted driving in a motion-based driving simulator to distracted driving (hands-free cell phone conversations, common in-vehicle tasks) either while sober or combined with alcohol (BAC 0.08). The results indicated that during a car following scenario, drivers engaged in the conversations or completing in-vehicle tasks were more impaired than drivers that were not involved in any distraction task. Indeed, both the cell phone and in-vehicle sources of distraction were generally more impairing than intoxication at the legal limit.

INTRODUCTION

There is some debate regarding cell phones as a risk factor in traffic crashes, and their relative risk compared to other existing secondary tasks drivers may perform in the vehicle. Now that that there are many states intending to introduce traveler information systems (e.g. 511 Traveler Information Services) and companies offering wireless services (e.g. Yahoo! Driving Directions) that may be accessed with cell phones while driving, there is an even greater need for relevant research to determine the risk of secondary task distractions.

A risk can be assumed for any task that demands driver attention such that there are fewer mental resources remaining to allocate to the primary driving task. Given that operating a cell phone necessarily involves some attention, the key question is not if cell phone use imposes a risk, but rather, if the amount of risk is unacceptable.

An acceptable risk threshold can be assessed in relative terms by comparing cell phone use to other common risk factors. First, there is a range of common in-vehicle tasks that are routinely engaged by the driving population, which may be considered a baseline of "consensual risk". Second, demonstrable limits have been set for other impairment factors such as alcohol (BAC 0.08) since it is already widely regulated (NCADD, 2000). The risk imposed by these legislated limits can also be considered a baseline of "sanctioned risk".

This project aimed to assess the "relative" risk of cellular phone use on driving impairment in comparison to commonly accepted in-vehicle tasks as well as a Blood Alcohol Content (BAC) of 0.08 which is currently legislated as an impairment threshold.

METHODS

48 males over the age of 21 participated in our mixed model design. The study used an immersive motion-base driving simulator linked to a full-sized vehicle with realistic operational controls and instrumentation. The visual scene is projected with a high-resolution (2.5 arc-minutes per pixel) five-channel 210-degree forward field of view with rear and side mirror views. Auditory feedback and haptic feedback were provided by a 3D surround audio system, subwoofer, car body vibration, and a three-axis electric motion system (roll, pitch, z-axis).

Participants experienced a continuous primary task of car following on a rural two-lane highway where they were to constantly maintain a safe headway. The "coherence technique", established by Brookhuis, de Waard, and Mulder (1994) and modified by Ward, Manser, de Waard, Kuge and Boer (2003) was used since it has been found to be sensitive to both increased primary and secondary task loading. In this application, the participant driver must follow a lead vehicle as it changes speed with a varied time cycle and fixed speed amplitude. (Note: the lead vehicle's taillights did not light during decelerations, as they would not typically light on a vehicle releasing the accelerator in order to slow down in higher-speed highway conditions.)

- Practice – 30 seconds of driving between 60 and 70 mph with a randomly varying cycle of .02 Hz to .04 Hz (i.e., cycles of 25 to 50 seconds).
- Low Frequency Range – 2 minutes of driving between 55 and 75 mph with a randomly varying cycle of .02 Hz to .04 Hz (i.e., cycles of 25 to 50 seconds).

- High Frequency Range – 2 minutes of driving between 55 and 75 mph with a randomly varying cycle of .06 Hz to .12 Hz (i.e., cycles of 8.33 to 16.66 seconds).

This task is representative of a continuous driving task requiring sustained vigilance, and therefore, is relevant to the study of driver distraction and traffic safety.

Two types of secondary task were developed to represent different combinations of resource allocation to information input, processing, and output response in relation to primary driving task resources (Wickens, 1984). The first was an in-vehicle secondary task using a Compaq iPAQ mounted on the dashboard. After a notification flash, the screen showed an image of a radio or HVAC system setting to signify that the participant was to copy the setting depicted. For example, if we wanted them to change the heat setting to maximum heat, we presented an image of that HVAC knob turned all the way into the red. The four categories of settings were buttons with indicator light, airflow setting knob, temperature setting knob, and CD track buttons. Pictures were selected randomly so that no category was picked sequentially and that subsequent selections from the same category were not repeated.

The (hands-free) cell phone conversation tasks were based on questions from the Rosenbaum Verbal Cognitive Test Battery (Waugh et al., 2000). These tasks are intended to represent different levels of mental demand experienced while conversing on a hands free phone. The conversations were automatically triggered as .wav files embedded in the driving scene using an aftermarket hands-free speaker system. The experimenter monitored the conversations to make sure the participant was completing them and to motivate the participant by engaging in naturalistic follow up questions. There were three categories of this task:

- Repeating a sentence
- Solving a verbal puzzle
- A monologue based on a stated topic

The cell phone task was an audio input and verbal output task while the in-vehicle task was a visual input and manual output task. Thus the two tasks required different modes of attention, processing, and response in contrast to driving that is primarily a visual input and manual output task.

During each experimental drive participants were to compete one of three levels of task workload: baseline driving with no additional task, driving while completing in-vehicle tasks, or driving while engaged in hands-free cell phone conversations. Task condition order was counterbalanced using a Latin Square design. No significant differences were found between the two secondary task conditions for how much subjective effort was needed to complete them ($p= 0.90$) or how generalizable they are to similar tasks completed in the real world ($p= 0.45$).

BAC group was a between subjects variable and participants were blind to their assignment to either the control or alcohol group. The control group was given a placebo beverage consisting of 7 parts cranberry juice in an alcohol-swabbed cup. The alcohol group was administered a beverage containing a mixture of 1 part ethyl alcohol (190 proof) to 6 parts cranberry juice. Beverage volume administered was based on body weight to achieve a predicted BAC of 0.08 at 50 minutes from consumption based on the 8/10 version of Widmark's formula (NHTSA, 1994). During the experiment, participant's BAC was measured using a Draeger breathalyzer after the practice driver and each experimental drive. There was a significant difference in BAC between the Alcohol and Control conditions [$F(1,44)= 832.2$, $p< .001$]. As expected, participants in the Alcohol group (BAC $M=0.073$, range=0.045 to 0.108) had significantly higher BACs than those in the Control group (BAC $M=0.001$, range=0.000 to 0.017) for all three Task Conditions. There were no significant differences between our sober and intoxicated drivers in terms of age, years driving, sensation seeking, weekly alcohol consumption, annual mileage, or careless driving or speeding convictions (all $p> 0.30$).

During the continuous car following task, the following were taken as measures of primary task performance:

- Variation (standard deviation) in time headway [seconds]
- Coherence – a measure of correlation between the speed signals from the lead vehicle and the participant's vehicle.
- Modulus – a measure representing the amplification of the participant's speed signal with respect to the load vehicle.
- Phase shift (delay) – a measure of the lag between the speed signals of the lead vehicle and the participant's vehicle.
- Steering entropy – a measure of the predictability of the driver's steering responses (Boer, 2000).

Good performance on these measures would be indicated by larger (positive) coherence values as well as smaller variation in time headway, smaller delays, and modulus values near 1. Impaired performance would be indicated by smaller coherence as well as larger variation in time headway, larger delays, and modulus values different from 1.

Simulator Performance measures were analyzed using a 2 (BAC Group: alcohol, control) x 3 (Condition: baseline, cell phone, in-vehicle) x 2 (Frequency Range: low, high) mixed model ANOVA. To avoid problems with potential sphericity in the data, Huynh-Feldt results were used for all main effect and interaction ANOVA results. Follow up tests to significant ANOVA main effect results compare Task Conditions using the Wilcoxon (Z_W) non-parametric signed-ranks test.

In addition to main effects and simple effects of the simulator performance variables, specific comparisons of interest (benchmark tests), were examined to determine the relationship between intoxicated and sober driving. Mann-Whitney (Z_U) non-parametric paired test were used for the following comparisons:

- Intoxicated drivers in the Baseline condition to sober drivers completing the In-Vehicle secondary task
- Intoxicated drivers in the Baseline condition to sober drivers completing the Cell Phone secondary task
- Intoxicated drivers in the Baseline condition to sober drivers in the Baseline condition

RESULTS

For variability in time headway, there was a significant main effect for Task Condition [F(2,88)= 27.7, p< .001]. Headway variability was significantly higher during the in-vehicle task condition (M= .458) compared to the baseline (M= .339) [W_z= 4.51, p< .001] and cell phone [W_z = 2.65, p< .01] conditions. Moreover, headway variability was also significantly higher during the cell phone condition (M= .386) compared to the baseline condition [W_z= 2.42, p< .01]. In terms of benchmark tests (see Figure 1), the headway variability *during the entire car following task* was significantly higher while sober and performing in-vehicle tasks (M= .460) compared to being drunk and performing no secondary tasks (M= .335) [U_z= 2.52 p< .01].

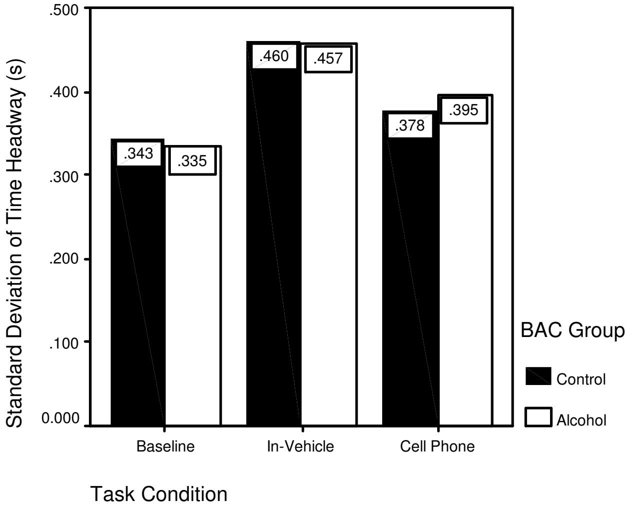

Figure 1 – Standard deviation of time headway (overall) during car following by BAC group

There was a significant main effect of coherence for Task Condition [F(2,88)= 28.60, p< .001]. Coherence was significantly worse during the in-vehicle task condition (M= .706) [W_z= 5.53, p< .001] and the cell phone condition (M= .766) [W_z = 2.97, p< .01] compared to the baseline condition with no secondary tasks (M= .809). Moreover, coherence was significantly worse during the in-vehicle task condition compared to the cell phone condition [W_z= 3.69, p< .001]. In terms of benchmark tests (see Figure 2), coherence *during the high frequency speed range* was worse while sober and performing in-vehicle tasks (M= .732) compared to being drunk and performing no secondary tasks (M= .796) [U_z= 2.19, p< .05].

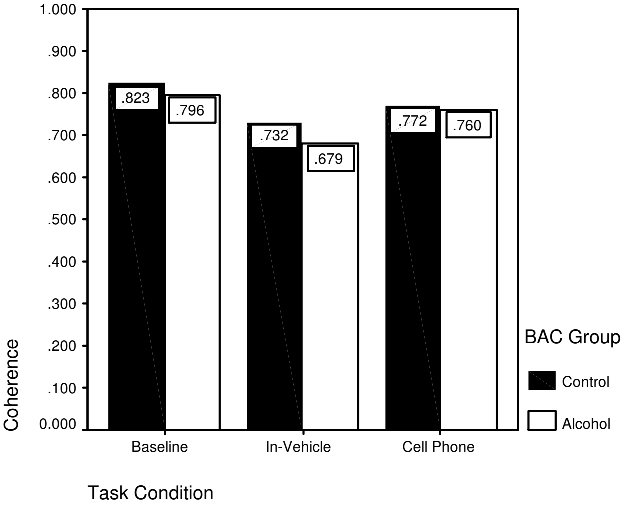

Figure 2 – Coherence *during the high frequency* car following scenario as a function of BAC Group and Task Condition.

For modulus there was a significant main effect for Task Condition [F(2,88)= 7.74, p< .001]. Modulus was significantly lower during the in-vehicle task condition (M= .744) compared to the baseline (M= .812) [W_z= 3.55, p< .001] and cell phone (M= .791) [W_z= 3.15, p< .01] conditions. There was no significant difference in modulus between the baseline and cell phone conditions.

For phase shift (delay), there was a significant main effect for Task Condition [F(2,88)= 27.7, p< .001]. The delay was significantly longer during the in-vehicle task condition (M= 5.34) compared to the baseline (M= 4.12) [W_z= 5.11, p< .001] and cell phone (M= 4.35) [W_z= 4.31, p< .001] conditions. Moreover, the delay was marginally longer during the Cell Phone condition compared to the baseline [W_z= 1.61, p< .10]. In terms of benchmark tests (see Figure 3), the delay *during the entire car following task* was significantly slower while sober and performing in-vehicle tasks (M= 5.16) compared to being drunk and performing no secondary tasks (M= 4.10) [U_z= 2.00 p< .05].

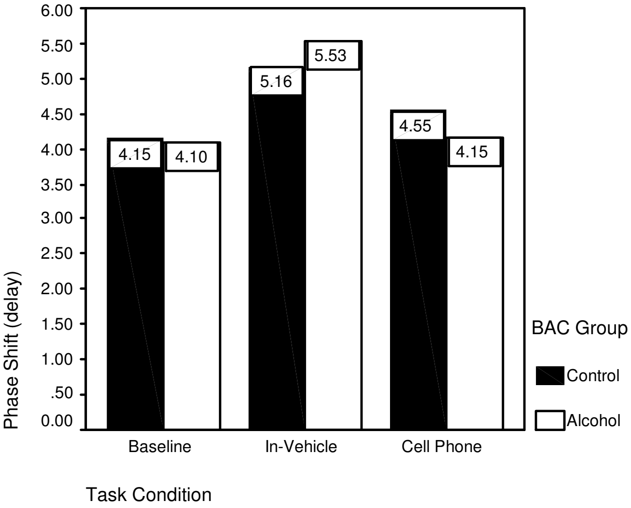

Figure 3 – Phase shift (delay) during the car following scenario as a function of BAC group and Task Condition

For steering entropy there was a significant main effect for Task Condition [F(2,88) = 23.10, p < .001]. There was significantly less predictable steering activity during the in-vehicle task condition (M= .679) compared to the baseline (M= .559) [W_z = 5.36, p < .001] and cell phone (M= .635) [W_z = 2.81, p < .01] conditions. Moreover, steering activity was also significantly higher during the cell phone condition compared to the baseline condition [W_z = 4.71, p < .001]. In terms of benchmark tests (see Figure 4), the steering entropy *during the entire car following task* was significantly higher while sober and performing in-vehicle tasks (M= .680) compared to being drunk and performing no secondary tasks (M= .542) [U_z = 2.52 p < .01]. Moreover, steering entropy was also marginally higher while sober and engaged in cell phone conversations (M= .651) compared to being drunk and performing no secondary tasks [U_z = 1.71 p < .10].

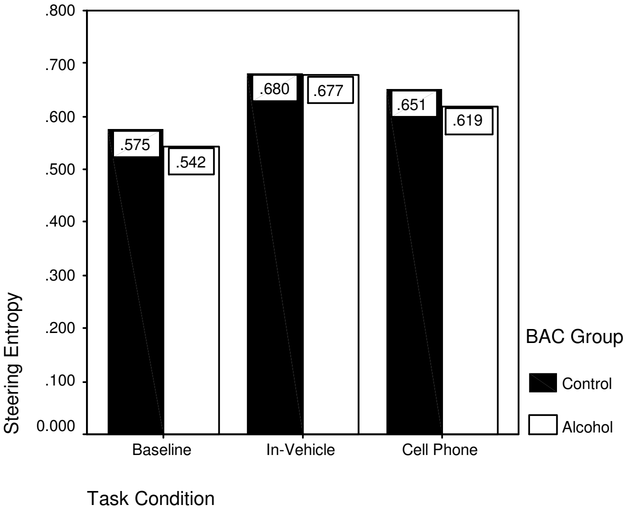

Figure 4 – Steering entropy during car following scenario as a function of BAC Group and Task Condition

DISCUSSION

Driving performance while conversing on the cell phone and during the in-vehicle task condition was consistently worse compared to baseline driving with no secondary task. Notably, sober drivers interacting with in-vehicle tasks were often more impaired than drunk drivers without any secondary task. This is consistent with the inherent greater conflict for visual input and manual output resources shared by both driving and the in-vehicle tasks. However, impairment of driving performance during the cell phone condition was usually less severe compared to driving while interacting with in-vehicle tasks.

The level of alcohol impairment produced was intended (and succeeded) to be at the current legislated limit of BAC 0.08. However, few results showed significance for the alcohol comparison. Whereas deterioration of driving skills has been shown to begin at BAC 0.05 (Council on Scientific Affairs, 1986), the level of intoxication may not have been sufficient to show impairment in the scenarios used in this study. In fact, all 24 alcohol condition drivers had a peak BAC of at least 0.05 yet only 9 peaked above 0.08, showing that a majority of the drivers did not even peak at a the legislated limit let alone show impairment from a consistently high level of intoxication. Moreover, participants might have found it easier to compensate for alcohol impairment than the secondary tasks. That is, general impairment from alcohol may be more easily compensated for than distraction whereby the eyes are directed away from the roadway and the hands are removed from the steering wheel. Similarly, unlike alcohol intoxication, the distraction tasks interfered with specific resources (e.g. visual processing, manual response). This amount of impairment from resource competition may have been greater than the impairment of generic resources by alcohol.

Instituting regulations to ban hand-held cell phone usage is a start to limiting the number of crashes they may produce. Even so, new evidence suggests that such bans do not affect long-term behavior of drivers without sustained enforcement and publicity (Royal, 2003). As seen in this study, this is a far more complex issue than holding the phone; in-vehicle tasks (and by inference – hand-held phones) caused detriments in driving performance due to having drivers physically manipulate items, but cell phones also contributed to poor performance through virtue of only verbal communications. In addition, it was shown in some instances that sober drivers performing in-vehicle and cell phone tasks had poor vehicle control in comparison to intoxicated drivers not performing any task. Future efforts should emphasize educating the public on when they may be affected by their decision to partake in consensual risks as well as potentially legislating dangerous consensual risks into sanctioned risks.

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