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DRIVING PERFORMANCE WHILE ENGAGED IN MP-3 PLAYER INTERACTION: EFFECTS OF PRACTICE AND TASK DIFFICULTY ON PRT AND EYE MOVEMENTS

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Summary: The purpose of this study was to examine the effects of iPod interactions on driver performance over several sessions to determine the distraction effect of iPods on driver performance, as well as to see if performance decrements declined with practice. Nineteen younger drivers (mean age = 19.4, range 18 to 22) participated in a seven-session study in the University of Calgary Driving Simulator. Drivers encountered a number of critical events such as pedestrian incursions, lead vehicle braking, and pullout vehicle events, on the roadways. These events were encountered both while driving alone and when performing iPod tasks of varying difficulty. Participants' hazard response, frequency of collisions and eye movement measures were examined to determine if there were any changes in performance related to iPod distraction and practice effects. Increases in perception response time (PRT) and frequency of collisions were found during the difficult iPod interactions. The number and duration of glances made into the vehicle increased significantly while performing the difficult iPod interactions, reducing the number of glances made to the roadway. Over the course of the sessions, performance improved significantly in all secondary task conditions, but performance decrements still remained in the difficult iPod condition compared to the baseline.

INTRODUCTION

Driver distraction from a host of sources has been cited since the 1930s as a potential crash contributor (Caird & Dewar, 2007). Driver distraction is the momentary or transient redirection of attention from the task of driving to a thought, object, activity, event or person, and encompasses actions such as eating, grooming, talking with a passenger and so forth (Stutts et al., 2003). Some research has examined the gamut of distractive activities, but in general driver distraction research in recent decades has focused predominantly on the impact of cellular or mobile telephones on driver performance. Through this research we know that interacting with a cellular phone while driving increases crash risk (McEvoy et al., 2005; Redelmeier & Tibshirani, 1997), reaction time to hazards (Caird, Scialfa, Ho, & Smiley, 2004; Horrey & Wickens, 2006) and constrains the breadth of eye movements to the roadway (Chisholm et al., 2006; Green, 2007; Green & Shah, 2004; Recarte & Nunes, 2000; 2003).

While an abundance of information is known about cellular phone distraction, information on the distractive potential of other common activities is relatively limited. Radio, 8-track, cassette, CD, and now MP-3 players have been or are now part of our vehicles. For instance, almost 92% of drivers were observed, in a naturalistic study by Stutts et al. (2005), using audio/music devices. As well, approximately 11% of all distraction-related crashes are attributed to adjusting the radio/cassette/CD (compared to 1.7% for talking/listening/dialling a cell phone). Many drivers use music devices, and this use has been associated with an increase in crash risk (Klauer et al., 2006).

MP-3 players generally, and iPods specifically, are more complex than common CD players or radios. Song titles, artists' lists, other menu options, functions and interactions require more visual attention and cognitive problem solving than previous audio technologies. From a practical point of view, the more visually complex a device is, the greater the chance that the eyes are going to be drawn away from the roadway and into the vehicle. The frequency of glances that are made into the vehicle to perform a task and the length of these glances have been suggested as indicators of unsafe behaviors (Green & Shah, 2004). Glancing repeatedly into the vehicle increases the probability of missing critical information, thereby increasing the potential crash risk.

To date, the impact that iPod interactions have on driver attention and performance has not been sufficiently addressed by researchers. The purpose of this study was to examine the effects of iPod interactions over seven sessions to determine if driving performance decrements declined with practice. As drivers become more accustomed to the testing environment and secondary tasks, improvements in performance are expected to occur. Only one previous study has examined the longer-term effects of in-vehicle distraction. Shinar, Tractinsky, and Compton (2005) found that drivers became more proficient in vehicle control measures while conversing on a cellular phone over repeated trials. Meta-analyses of cell phone conversation studies have shown that lateral and longitudinal vehicle control measures are less affected by the presence of in-vehicle distractors (Caird et al., 2004; Horrey & Wickens, 2006). To reconcile these differences, an event-based paradigm (Chisholm et al., 2006) was used to determine if drivers could respond sufficiently to critical traffic events with iPod interactions with extended practice.

METHODS

Nineteen younger drivers 18 to 22 (M = 19.4) participated in seven weekly, hour-long sessions in the University of Calgary Driving Simulator (UCDS). Drivers had to drive at least 10,000 kilometers per year and hold a class 5 license, which is required in Alberta to drive passenger vehicles.

A complete description of the UCDS can be found in Caird et al. (2006). Briefly the UCDS is a moderate fidelity, fixed-base simulator with 150-degree projected field of view. Scenarios were developed and run in HyperDrive ™ (v. 1.9.25), and video data was transferred and captured by a SimObserver system that immediately digitized the video feed from four cameras located inside the simulator. Video data was analyzed using Data Distillery, an offline video analysis system. Eye movements were captured during half of the experimental sessions (i.e., sessions 2, 4, and 6) using an Applied Science Laboratory (ASL) 501 eye tracking system. The ASL-501 uses a lightweight, head-mounted, infrared corneal reflection system that allows data collection while head and body movements occur (see Figure 1). Eye position is sampled at a rate of 60Hz and the system has a reported accuracy of one degree.

Figure 1. Participant wearing eye movement system and interacting with iPod mounted on the center column (left). Events used in the study: pedestrian (upper left), vehicle pullout (upper right), lead vehicle braking (lower left) and late yellow light (lower right).

Procedures

The first session was used to screen out potential participants for vision defects and susceptibility to simulator sickness. Far and near visual acuity, contrast sensitivity, and color vision tests were performed, and participants drove through a ten-minute screening drive to identify and remove those participants who experienced motion sickness in the simulator. Any participant who failed to meet the screening requirements was not allowed to participate in the study. Those who successfully passed the screening session were signed up for six weekly sessions at the same time of day. Remuneration for the sessions increased incrementally throughout the six sessions, each participant received a total of $200.00 ($CAN) for the successful completion of all seven sessions. A prize draw was also conducted for those who completed all of the sessions.

During the six experimental sessions, drivers performed a number of interactions with the iPod that was mounted on the center console of the simulator. Two difficulty levels of iPod interactions were performed in the subsequent six experimental sessions. Easy iPod tasks involved tasks with one or two interactions, such as turning off the iPod, pausing a song, and scrolling ahead a couple of songs. The difficult iPod tasks involved locating and playing specific songs from amongst 900 titles in the song menu system. While performing these tasks, three types of critical events were encountered—namely, pedestrian, vehicle pullout, lead vehicle braking—and one less critical late yellow light (see Figure 1 above). Each critical event was designed to be a surprise event for the driver and required timely response to avoid a collision. Event placement within a drive and the order of drives encountered within and over sessions were counterbalanced and randomized. Eighteen experimental drives were created and used during the six experimental sessions (also see Chisholm, 2006, for additional details).

RESULTS

Data were analyzed using a repeated measures ANOVA with secondary task (easy iPod, difficult iPod, and Baseline), critical event (pedestrian, lead vehicle braking, and pullout vehicle), and occurrence of the event (3 per condition) as the within-subjects variables. *Occurrence* refers to the order of each event type within each secondary task condition. For example, pedestrian occurrence two for the easy iPod task pertains to the second time that the pedestrian event occurred while participants were performing the easy iPod task. Three of 11 dependent variable analyses are presented; namely, perception response time (PRT), collisions and eye movements (Chisholm, 2006).

Perception Response Time (PRT)

Perception response time refers to the total time (in seconds) from event onset until the participant responded by applying pressure to the brake pedal. Performing the difficult iPod interactions significantly impaired drivers abilities to respond in a timely manner to the critical events, $F(2, 37) = 9.76$, $p < .001$. While no differences in PRT were found between the baseline ($M = 1.12$, $SE = .03$) and easy iPod ($M = 1.17$, $SE = .03$) conditions, PRT in these conditions were significantly faster than those found for the difficult iPod conditions ($M = 1.30$, $SE = .03$), $p < .05$. PRT in all conditions improved over the course of the study, $F(2, 39) = 8.87$, $p = .001$, with the fastest PRT in the 3rd occurrence of the events ($M = 1.11$, $SE = .03$) compared to both the 1st ($M = 1.29$, $SE = .03$) and 2nd ($M = 1.21$, $SE = .03$) occurrences, $p < .05$ (see Figure 2).

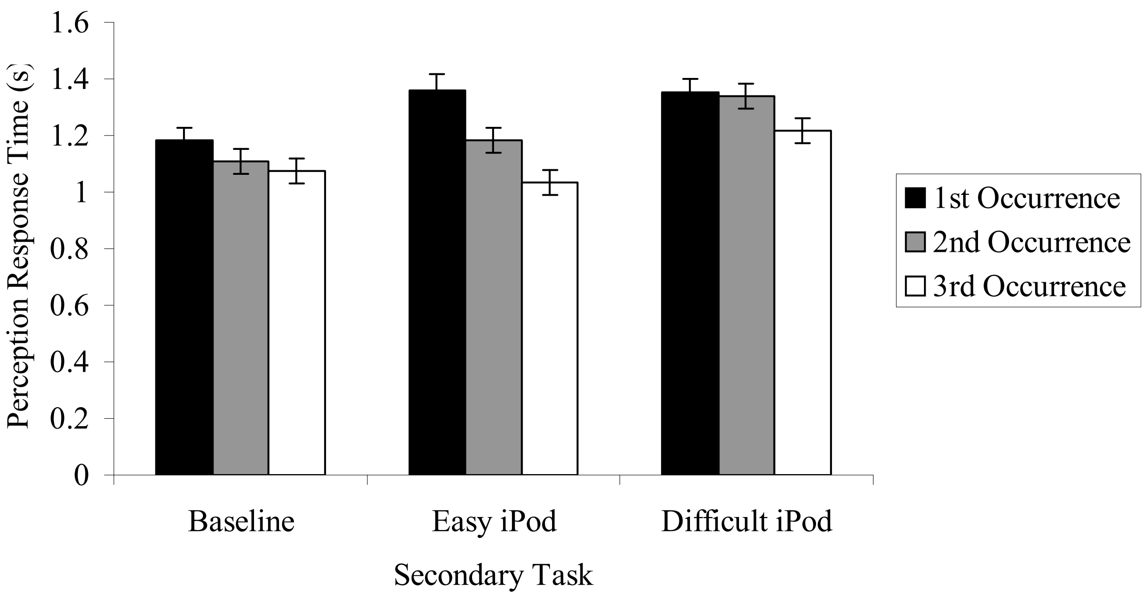

Figure 2. Perception Response Time (PRT) by secondary task and occurrence

The various events also impacted PRT differentially, $F(2, 368) = 35.78$, $p < .001$, with longer values with the lead vehicle braking events ($M = 1.35$, $SE = .03$) followed by the pullout vehicle ($M = 1.19$, $SE = .03$), and the fastest in the pedestrian event ($M = 1.04$ $SE = .03$), all of which differed significantly from one another, $p < .05$. Post-session interviews revealed that the lead vehicle braking events were difficult to anticipate, whereas participants felt they were able to adequate anticipate where a pedestrian might appear based on road geometry information. The two-way interactions between occurrence and event type, $F(6, 475) = 3.16$, $p = .005$, and between secondary task and event type, $F(6, 475) = 4.12$, $p < .001$, were significant. The significant three-way interaction among occurrence, secondary task, and event type was also significant, $F(7, 368) = 7.45$, $p < .001$. Follow-up analyses were performed separately for each event type. Secondary task had a significant effect on PRT to the pedestrian event, $F(2, 36) = 6.27$, $p = .005$. The fastest PRT to the pedestrian event was observed with the easy iPod tasks ($M = 0.90$, $SE = .05$), which was significantly faster than the difficult iPod task ($M = 1.15$, $SE = .04$), $p < .05$. Neither iPod task differed significantly from the baseline ($M = 1.03$, $SE = .04$), $p > .05$.

Collisions

Frequency of collisions encountered by participants with the vehicles and pedestrians used in the events was calculated based on headway data. A total of 513 event occurrences were included in this analysis, which represents all the experimental combinations of the independent variables (i.e., pedestrian, lead vehicle braking, and pullout vehicle) for each of the secondary tasks (i.e., baseline, easy iPod, and difficult iPod).

In total, 115 collisions were observed over the six sessions. Secondary task had a significant effect on collision frequency, χ^2 (2) = 11.67, $p = .003$. Twenty-eight collisions occurred during the baseline drives, 34 during the easy iPod condition, and 53 in the difficult iPod interactions. Significant differences were found between the difficult iPod and both the baseline and easy iPod conditions, $p < .05$. Frequency of collisions also decrease significantly as a function of occurrence, χ^2 (2) = 13.28, $p = .001$. Fifty-two collisions were observed in the 1st occurrence, decreasing to 39 in the 2nd, and finally 24 collisions were observed in the 3rd occurrence of the events. Significant differences were found between the 1st and 3rd occurrences, as well as between the 2nd and 3rd occurrences, $p < .05$.

Eye Movement Measures

Video data analysis was analyzed using DataDistillery software. *Glances* were defined as consecutive fixations to an area of interest (i.e., in the vehicle, on road) not including saccade transition time and blinking behaviour (International Standards Organization, 2002). The percentage of total glance duration made onto the roadway and into the vehicle were calculated based on the time it took to complete the iPod tasks and comparative one-minute baseline measure. Comparisons were made between all secondary tasks to determine percentage of time drivers glanced to these areas during task performance.

On-road glances. During completion of the difficult iPod tasks, drivers spent only approximately 16% of task time ($SE = 1.51$) looking at the roadway itself, compared to 24% of time in the easy iPod condition ($SE = 1.73$), and 28% in the baseline ($SE = 1.78$), $F(2, 42) = 8.58$, $p = .001$. No differences were found between the latter two conditions, $p > .05$.

The two-way interaction between secondary task and roadway geometry was also significant, $F(4, 176) = 8.70$, $p < .001$. This interaction is due to the fact that on the residential roadways, the percentage of task time glancing at the road was significantly lower at 16% in the difficult iPod condition ($SE = 1.96$) compared to the baseline at 33% ($SE = 3.25$), $p < .05$. Similarly, in the urban section of road, 11% of the difficult iPod task time was spent looking at the road compared to 29% in the baseline, $p < .05$. However, on the freeway roads there was no difference found between the difficult iPod (19%) and baseline (24%) conditions, $p > .05$.

In-vehicle glances. As expected, performing secondary tasks required additional attention to be redirected away from the roadway and into the vehicle, $F(2, 39) = 178.28$, $p < .001$. Specifically, 51% ($SE = .93$) of difficult iPod task time was spent looking into the vehicle, compared to 27% ($SE = 1.08$) in the easy iPod and 14% ($SE = 1.35$) in the baseline conditions, all of which significantly differed, $p < .05$. Road geometry also impacted allocation of glances into the vehicle, $F(2, 220) = 7.21$, $p = .001$. On residential roads, drivers were more inclined to spend a greater amount of task time looking into the vehicle ($M = 33.51$, $SE = 1.01$) than on either the urban ($M = 27.98$, $SE = 1.22$) and freeway ($M = 29.20$, SE 1.15) roads, $p < .05$.

CONCLUSIONS

This study examined the effects of repeated iPod interactions on driver performance to determine if performance decrements decreased with practice. A multi-measure approach was used to understand the range of driver performance dimensions including hazard detection and response and eye movements. A comprehensive and convergent view of the effects of distraction on driver performance with practice is evident. iPod interactions impaired drivers' ability to respond to hazards on the roadway Over the events and occurrence, PRT increased by 0.18 s or 16% over the baseline when performing the iPod difficult task, depending on event type. In addition, a higher frequency of collisions occurred while interacting with the iPod difficult tasks (53) than during either the iPod easy (34) or the baseline drives (28). Serial sampling between the roadway and in-vehicle during task completion impairs perception and response to hazards, which directly led to an increase in the frequency of collisions observed.

The purpose of a multiple-session approach was to determine if repeated practice of the secondary task while driving in demanding contexts would lessen the detrimental impact of the distraction on driver performance. Single session or cross-sectional studies may not provide an accurate picture of cumulative distraction effects. Although decreases in PRT were found with practice, performance with the difficult iPod task never achieved the same level of performance as in the baseline condition. Even after additional practice, drivers were still unable to improve their dual-task performance to the safe baseline level.

Results from the current study indicate that some iPod tasks performed in vehicles are problematic. Specifically, performing difficult iPod tasks while driving impairs perception and response to hazards and increases the frequency of observed collisions. These difficult interactions also require more glances to be made into the vehicle and take longer to complete. Many vehicle manufacturers are including the capability to integrate iPods into vehicles as a "lifestyle enhancement." The multivariate results suggest that access to difficult iPod tasks while vehicles are in motion should be curtailed.

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