Testing assumptions implicit in the use of the 15-second rule as an early predictor of whether an in-vehicle device produces unacceptable levels of distraction

James Reed-Jones, Lana M. Trick*, Michael Matthews

Department of Psychology, University of Guelph, Guelph, Ontario, Canada N1G 2W1

Received 13 June 2007; received in revised form 1 August 2007; accepted 31 August 2007

Abstract

Given the proliferation of in-vehicle technologies, techniques must be developed to ensure devices do not produce unacceptable levels of distraction. One approach is to use static time on task (e.g., the 15-second rule). However, this practice makes three critical assumptions: (1) static time on task predicts time on task while driving; (2) time on task measured in a hazard-free environment predicts time on task when drivers expect hazards; (3) time on task predicts perceived distraction, collisions, and driving errors. To test these assumptions, two tasks were compared in 32 drivers using a driving simulator. The tasks were manipulating controls of a radio/tape deck and dialling a hand-held cellular phone. Static time on task underestimated dynamic time on task, though the differences between tasks were roughly consistent across testing conditions, with the cellular task taking more time. Participants who expected hazards required slightly more time on task than those who did not, but the effect was only marginal \( p = 0.09 \) and consistent across tasks. Finally, the device with higher static time on task also produced significantly more lane deviations and perceived interference, though the predicted pattern of results did not emerge for collisions and hazard response time.

1. Introduction

The number of in-vehicle technologies is increasing. Some have the potential to distract—a serious problem given evidence that inattention/distraction plays a role in up to 78% of crashes (Neale et al., 2005). Distraction is defined as the diversion of attention produced by a compelling activity or event (Treat, 1980) and methods and standards for determining what constitutes unacceptable distraction while driving must be developed before crash data accumulate (Burnett et al., 2004). To be maximally useful these methods should be specific and applicable early in the design process, before substantial amounts of money have gone into product development. This explains the appeal of SAE Recommended Practice J2364: “the 15-second rule” (2002), which uses static time on task to determine what constitutes acceptable distraction. However, the use of static time on task is based on a string of assumptions, and this study tests these assumptions by assessing consistency among measures across two in-vehicle tasks.

Several theories are relevant to this issue, but all predict that when driving and using an in-vehicle device require the same limited resource, there will be interference, which is to say that performance on one or both tasks will suffer. For example, according to Baddeley (2003), interference occurs when driving and a secondary task tap the same specific working memory resource (the phonological loop, visual-spatial sketchpad, or central executive). Wickens (2002) maintains interference occurs when tasks share common processing stages (early perceptual vs. late central processing), modalities (auditory vs. visual), or response types (verbal vs. manual). There have even been attempts to model multi-task interference for specific devices (Horrey et al., 2006; Salvucci, 2005) but at this point the models are not so well developed that they can predict whether any arbitrary device would produce unacceptable levels of distraction. This is because the question of what constitutes “acceptable” is in itself problematic.

There have been two approaches to determining what constitutes acceptable distraction. The first involves setting up relative standards—measuring distraction while using a new technology...
relative to distraction while performing a comparison task that is judged to be safe. If the new device produces more distraction than the comparison task, then the device produces unacceptable levels of distraction. One problem with this approach is that it relies on choosing an appropriate comparison task, and this decision can engender debate (Haigney and Westerman, 2001; McKnight and McKnight, 1993). It could be argued that when determining whether a given device compromises driving performance, the only valid comparison is baseline driving (driving with no secondary task). However, this might be unfairly restrictive. There are already a large number of activities carried out while driving (Neale et al., 2005). Some are necessary, some are inevitable (given human nature), and some are even beneficial, as occurs when a secondary task helps drivers stay alert (Verwey and Zaidel, 1999). In some situations it might be better to consider a comparison task that represents what the driver would be doing instead of using the new technology. For example, when drivers are lost they may resort to driving while trying to read a map, and consequently it might be important to include a comparison task that involves driving while reading a map when evaluating route guidance systems. However, finding out what drivers would be doing instead also demands research, and that would further delay the process of determining whether a given device produces unacceptable distraction.

A second approach involves using comparison tasks based on devices that are already in vehicles, such as radio and climate controls. These devices are considered safe—at least based on legal precedent (using them has not yet been made illegal) and there is research on the interference they produce (e.g., Wierwille and Tijerina, 1998). Nonetheless, this strategy has its own complications. For example, the choice of what to make the “standard” radio comparison task can be fraught with controversy. The spatial layout of controls can vary as can the activities involved in using the device, and ultimately, comparing the distraction produced by using a radio with that produced by a new technology may be akin to comparing apples and oranges. It is unlikely that a perfect match can be found for every arbitrary new in-vehicle technology and an already existing device. However, if a decision must be made about whether a new device is acceptable, some comparison is better than no comparison at all.

Given the difficulties associated with finding the right comparison task for relative standards, the appeal of a second approach is understandable. The ‘15-second rule’ uses an absolute standard, a criterion of 15 s static time on task, to distinguish between devices that produce acceptable and unacceptable levels of distraction (Green, 1999; SAE, 2002). Although this method was initially designed for route guidance systems, some suggest that it could be extended to other devices (Green, 2000; Tijerina et al., 2000). This technique is not without problems. For example, it does not take into account how interruptible the task is (Noy et al., 2004). Nonetheless, this standard is specific and yet versatile, inexpensive, quick and easy to use. More important, it can be applied early in the design process, before substantial amounts of money have been devoted to product development. In contrast, relative standards typically require that the device be fully developed—at which time the device can be tested against a comparison task in an actual vehicle or driving simulator (time-consuming and expensive processes).

However, the use of absolute standards based on static time on task rests on a series of assumptions. The specific standard (15 s) originated from the judgments of an expert panel that concluded that most in-vehicle tasks take less than 15 s (SAE, 2002). The use of static time on task to predict behaviour in a moving vehicle assumes that tasks that take 15 s in a static vehicle will take around 15 s in a moving vehicle. Moreover, the use of static time on task in a hazard-free environment to predict time on task in a real driving environment assumes that drivers do not change the way they carry out the task when faced with periodic hazards on the road. Finally, and most important, the use of static time on task is based on the assumption that if drivers are interacting with a device, then they are not really paying full attention to the road, and thus driving errors and crash risk should increase with time on task (Tijerina, 2000).

In this study these assumptions were tested by comparing tasks that required interacting with two different device interfaces. One task was dialling a hand-held cellular phone while driving, a practice that is illegal in some jurisdictions (Cellular-News, 2006). Drivers perceive that dialling a hand-held phone is more distracting than dialling a hands-free model (Mazzae et al., 2004) and effects have been shown in lane keeping and hazard detection (Greenberg et al., 2003; Reed and Green, 1999). The second was manipulating radio/tape deck controls.

The goal was to investigate whether static time on task and other indices of performance yield consistent results when comparing the two tasks, a critical first step for establishing whether static time on task has predictive validity as an index for unacceptable distraction. Specifically, three things must be determined: (1) if the task that produces more distraction based on static time on task has higher dynamic time on task; (2) if the task with higher dynamic time on task in a hazard-free environment also has higher time on task when drivers are lead to expect hazards; (3) if the task judged to be more dangerous based on static and dynamic time on task also produces higher perceived distraction, collisions, and driving errors. If the assumptions that serve as a basis for the use of static time on task as an early index of unacceptable distraction are valid, then the difference between the two tasks should be consistent, whether it is static, dynamic (hazard-free), or dynamic (hazard-filled) time on task. Similarly, the device that is judged to be the most dangerous based on static time on task should also produce more perceived distraction, collisions, and driving errors.

2. Methods

2.1. Experimental design

This study had two parts. In the first (Experiment 1a), time on task was measured under static and dynamic hazard-free driving conditions (no pedestrians, cyclists, or cars intruded into the vehicle’s path). The goal was to determine whether static time on task predicted dynamic time on task for the two in-vehicle
tasks. All drivers in Experiment 1a had time on task measured under static (stationary vehicle) and dynamic (moving vehicle) conditions for both the radio and cellular phone tasks. Half the drivers started with static testing and the other half started with dynamic testing. For each type of testing, time on task was measured 10 times for each of the radio and cellular tasks, and trials on each task were intermixed and the order randomized for each driver.

In Experiment 1b, a different group of drivers was tested in relatively hazardous driving conditions (the same road but pedestrians, cyclists and vehicles periodically veered into the vehicle’s path). The goals of this part of the study were to determine whether time on task measured in relatively hazard-free conditions (Experiment 1a) could predict time on task in relatively hazardous conditions (Experiment 1b), and whether time on task could predict perceived distraction, collisions, and driving errors. Given that this study involved a two-lane highway with oncoming traffic and vehicles parked on the shoulders, lane deviations were considered driving errors. Driving performance was measured in three conditions: radio (driving while manipulating the radio controls), cellular (driving while dialling a cellular phone), and baseline (driving with no secondary task). Performance was measured 10 times in each condition with the trials intermixed and the order randomized for each subject.

2.2. Participants

Participants were 32 licensed drivers recruited through the university participant pool (16 each in Experiments 1a and 1b: 9 women and 7 men). All were right-handed, 17–21 years of age (mean = 19.0 years and 19.3 years in Experiments 1a and 1b respectively), and unfamiliar with the specific model of cellular phone employed in the study though 18 of 32 reported using some type of cellular phone while driving.

2.3. In-vehicle tasks

The study was about the distraction engendered by using device controls. Consequenly, attempts were made to minimize the demands for acquiring and memorizing new information (e.g. telephone numbers, radio channels) because cognitive interference affects driving behaviour even without visual/manual distraction (e.g., Harbluk et al., 2007). For the cellular task, participants dialled a familiar 11-digit number (e.g., their home number or one of a friend or family member). The task required picking up the phone, dialling, depressing the send key, holding the phone up to the ear for 1 s, depressing the end key, and returning the phone to the central console. Similarly, although there are a variety of radio tasks in the literature (e.g., Greenberg et al., 2003; Noy et al., 2004), in this study participants were required to turn on the radio, eject a tape, push three pre-set buttons on the radio (as if scanning the alternatives), push the tape back in, and turn the radio off. A recorded voice (“Begin cellular task” or “Begin radio task”) followed by a tone prompted drivers to begin secondary tasks. Timing ended after participants returned both hands to the wheel and said “Stop”. Although performance was expected to improve over trials in both tasks, practice effects were monitored by comparing performance in the first and last five trials.

The cellular phone was a Nokia 6188 used in hand-held mode and the console was 14 cm down and 33 cm to the right of the line of sight (assuming a driver height of 162 cm). The radio was the standard Saturn-equipped model, with rotary power dial, tape deck, and six push buttons for radio presets. Its position was 31.75 cm below and 33.66 cm to the right of the line of sight.

2.4. Driving simulator and scenarios

Testing was carried out in a fixed base Drive Safety DS-600c driving simulator: a Saturn four-door sedan equipped with all standard vehicle controls, augmented with audio and vibration transducers and force feedback (Fig. 1). The DS-600c simulator is of a type widely used in research simulation (e.g. Caird et al., 2002). Driving scenes were projected via LCD projectors onto six 7-ft screens that provided a 300° wrap-around virtual environment (250° in front and 50° in the rear).

Virtual environments were designed to simulate driving through an industrial park on a sunny day on a paved road with one lane in each direction and no median. There were no sidewalks but road shoulders were wide enough to accommodate parked vehicles; individual vehicles were parked at random intervals (averaging 2.5 vehicles per km). There was light ambient traffic that did not interfere with hazard events and obeyed all of the rules of the road (averaging 3.5 vehicles per km). Pedestrians and cyclists appeared on the side of the road at random intervals throughout the drive.

In Experiment 1a, static condition, drivers were seated in a parked car surrounded by a driving scene. In Experiment 1b and the dynamic condition of Experiment 1a, drivers negotiated functionally equivalent but visually distinct driving courses (scenery varied). Each course was composed of a series of straight roads connected by 7–10 long curves. There were no intersections. Within each course, there were a series of trial areas that were 400-m, two-way, single lane, straight sections of road, with no available turns. In Experiment 1a, all of these areas were hazard-free, and dynamic time on task was mea-
sured during these intervals, though the specific task that was measured in a given trial area varied randomly between participants. Each participant drove a randomly chosen two of the five driving courses.

In Experiment 1b, participants drove all five courses. The order that participants experienced the five courses was randomized across participants. Within the five courses there were 60 trial areas (10–13 per course). Of these 60 trial areas, 30 had hazards and 30 did not.

For the hazard areas, there were 10 trials each for the radio, cellular, and baseline conditions in which hazard response time was measured (5–7 visually distinct events per driving course). During hazard trials one of three entities (sedan, pedestrian, or bicyclist) entered the participants’ projected path of travel. Pedestrians could only enter from the right but the other entities emerged from either the right or left. Hedge rows occluded all of the driveways and in two thirds of the trials there was a vehicle obscuring the view. Entities emerged from behind the occluding scenery and would stop directly in the centre of the participant’s lane. This was timed so that the participant’s vehicle was 3.5 s away from where the entity stopped when the entity first became visible moving onto the roadway. The timing was chosen because participants were instructed to drive at 70 km/h and the average braking distance at 70 km/h is ~57 m. At this speed, a 3.5 s time to collision would allow for this 57 m braking distance with 10 m to spare, and would give drivers time to stop but no time to wait before braking. For the radio and cellular phone conditions, entities entered the vehicle path 4.5 s after the prompt for the secondary tasks. The simulator initiated tasks that occurred with a collision hazard in the same way as tasks that occurred without a collision hazard, and it was consequently difficult to predict when hazards would emerge.

The 30 trials in which there were no hazards were also evenly divided between the radio, cellular and baseline conditions. Velocity, lane keeping, and dynamic time on task were measured in those trial areas.

2.5. Procedure

Drivers were instructed to drive at 70 km/h (obeying all signs and traffic regulations) and to come to a complete stop in the event of a hazard, braking first and finishing any secondary tasks later. After a short familiarization course in which they were given two opportunities to practice each type of task while the vehicle was stationary and three opportunities to practice each task while driving, participants began the test courses. Test courses required 8–12 min each. In Experiment 1a, participants did two courses and time on task was measured in static and dynamic conditions when there were no hazard trials. In Experiment 1b, participants drove five test courses and had time on task, lane deviations, collisions and hazard response time measured. Perceived distraction was measured at the end of each driving course; participants rated the secondary tasks on a 1–6 scale, where 1 indicated “Had no noticeable effect on driving” and 6 indicated “Had a noticeable effect on driving—making it almost impossible”.

3. Results

Analyses involved testing the following assumptions: (1) static time on task predicts dynamic time on task for a driver in a moving vehicle; (2) time on task as measured in a relatively hazard-free environment predicts time on task when drivers expect hazards; and (3) time on task predicts perceived distraction, collisions, and driving errors.

To test the first assumption, data from Experiment 1a were analyzed. The 10 individual time trials for each task were divided into two groups of five to investigate practice effects in the time required to complete the task. Thus there were three factors: task condition (radio, cellular phone), type of test (static, dynamic), and trial group (first five, last five). Time on task was defined as the time between the tone at the end of the recorded message that prompted initiation of the secondary task and when the participant said, “Stop” (at which time the research assistant pressed a button in the simulator). As can be seen from Fig. 2, time on task was longer for the cellular than radio task (mean difference = 2.36 s, F(1,15) = 69.45, p < 0.001, partial η2 = 0.82) and longer in the dynamic than static conditions (mean difference = 3.67 s, F(1,15) = 181.75, p < 0.001, partial η2 = 0.92). However, there was no Task × Testing condition interaction: the magnitude of the time discrepancy between tasks was not significantly different in static and dynamic conditions.

Overall time on task decreased from the first to last five trials by approximately 0.61 s (F(1,15) = 20.68, p < 0.001, partial η2 = 0.58). There was also a Task × Type of Test × Trial interaction (F(1,15) = 5.17, p = 0.04, partial η2 = 0.26), such that the decrease in time on task from the first to last five trials was larger for the dynamic radio condition than the other conditions (M = 0.97 s as opposed to 0.50 s for the dynamic cellular, 0.62 for the static radio, and 0.68 for the static cellular conditions). There were no other significant effects.

To test the second assumption, time on task in a hazard-free environment (Experiment 1a) was compared to time on task as measured in an environment where drivers expected hazards (Experiments 1b). For this analysis there were three factors: task condition (radio, cellular), testing condition (hazard-free, hazard-filled), and trial group (first five, last five). Results are presented in Fig. 2. Average dynamic time on task was 1.29 s.

---

Please cite this article in press as: Reed-Jones, J., et al., Testing assumptions implicit in the use of the 15-second rule as an early predictor of whether an in-vehicle device produces unacceptable levels of distraction, Accid. Anal. Prev. (2007), doi:10.1016/j.aap.2007.08.018
less in the hazard-free condition than it was in hazard-filled condition but the difference was only marginally significant \((F(1,30) = 3.11, \ p = 0.09, \ \eta^2 = 0.09)\). As before, time on task was significantly higher for the cellular than radio task \((F(1,30) = 74.68, \ p < 0.001, \ \eta^2 = 0.71)\) and time on task for the first five trials was significantly higher than for the last \((F(1,30) = 13.49, \ p = 0.001, \ \eta^2 = 0.31)\). The drop in time on task from the first to last five trials was greater for the radio task than the cellular task \((F(1,30) = 4.42, \ p = 0.04, \ \eta^2 = 0.13)\). There were no other significant effects.

For the third assumption, time on task was related to other indices of distraction. As predicted, the cellular phone \(\) (the one that required greater time on task) produced significantly higher perceived interference ratings \((F(1,15) = 5.38, \ p = 0.03, \ \eta^2 = 0.26)\) \((\) see Fig. 3). Perceived interference ratings were gathered five times during the study \(\) (once after each of the five driving courses) but the amount of perceived interference did not change significantly from the first to last course \((F(4,60) = 1.29, \ p = 0.29)\). There was also no interaction between task and course \((F(4,60) = 0.50, \ p = 0.68)\).

It was also predicted that the device with the highest time on task would produce more lane deviations and collisions, and higher hazard response times. Performance was compared between the radio, cellular, and baseline conditions \((\) Fig. 4). However, to ensure drivers did not engage in compensatory slowing while carrying out the radio and cellular tasks, preliminary analyses compared average velocity during the hazard-free trial areas in the drive. These averages were calculated from the 400 m trial areas where the participants were either simply driving \(\) (baseline condition) or driving while carrying out a secondary task. There was no evidence of compensatory slowing.

In fact, participants drove 1 km/h faster with secondary tasks \((M = 70.32, 70.23, \) and \(69.29 \) km/h for the radio, cellular, and baseline conditions respectively: \((F(2,30) = 3.57, \ p = 0.04, \ \eta^2 = 0.19)\).

Lane deviations were counted as the number of times that a wheel completely crossed the center or curb lane markers \((\) regardless of the amount of time spent out of the lane). Task had the predicted effect on lane deviations: \((F(2,30) = 18.38, \ p < 0.001, \ \eta^2 = 0.55)\). Each condition differed significantly from the other two, with the greatest number of lane deviations occurring in the cellular phone condition and the least in the baseline condition. This result is consistent with the hypothesis
and studies of the effects of cellular dialling (Reed and Green, 1999; Greenberg et al., 2003) though not with studies on the effects of cellular conversation (Horrey and Wickens, 2006).

It was also predicted that the more time-consuming task would produce more collisions. The number of collisions was defined as the number of times the participant’s vehicle intersected with an imminent collision entity (car, pedestrian, or cyclist). This prediction was not supported. Although there were no significant differences between the three conditions in the number of collisions ($F(2,30) = 1.703, p = 0.20$), the trend was toward more collisions in the radio condition rather than the cellular phone condition (see Fig. 4).

Hazard response time was measured as the amount of time between when an entity entered the path of the vehicle and when the brake pedal was depressed. Task had a significant effect on hazard response time: $F(2, 30) = 4.56, p = 0.02$, partial $\eta^2 = 0.23$. L.S.D. post hoc comparison revealed that response times were significantly higher in the radio than baseline conditions ($p = 0.005$) though the difference between the cellular and baseline conditions was only marginal ($p = 0.054$). There was no significant difference between the cellular and radio tasks, though the trend was opposite to that predicted, with radio tasks having higher response times. Despite repeated hazards, hazard response time did not decrease significantly from the first to last five trials (mean difference = 0.02 s). No significant Task × Trial interactions emerged.

4. Discussion

Results provide provisional support for the first two of the three assumptions implicit in the use of static time on task to predict unacceptable distraction. Specifically, differences between the radio and cellular phone tasks were apparent regardless of how time on task was measured (static, dynamic hazard-free, dynamic hazard-filled), with the cellular task taking more time. However, time on task measured in static hazard-free environments underestimates the other indices of time task (see also SAE, 2004). First, it underestimates the effects of having to coordinate the task with driving (by 3.7 s in the present study), and second, it underestimates the effects that expectations for hazards produce (which added another 1.3 s in this study).

Support for the critical third assumption was not as uniform. The task judged most time-consuming based on static time on task (cellular phone dialling) produced higher perceived distraction ratings and more lane deviations, as predicted. Results were not in the hypothesized direction when it came to collisions and hazard response time though, where the differences between conditions were not as apparent, and if anything, the cellular task produced better performance. The dissociation between lane keeping and response to hazards in front of the vehicle is consistent with accounts that distinguish between the roles of ambient and focal vision in lane keeping and focal hazard detection respectively (Wickens, 2002). Higher hazard response times and collisions were to be expected in the radio condition, as participants were forced to look down to the radio console, which would compromise focal vision but leave ambient vision (and lane keeping) unaffected. In contrast, participants maintained a higher sightline during the cellular phone task. Cellular phones were held near the steering wheel (approximately 15–20 cm up from radio controls). Detailed eye movement information was unavailable, but post hoc analysis of global video records of driver behaviour revealed drivers spent longer looking towards the cellular phone than the radio controls when using the devices under hazard-free driving conditions ($M = 6.41$ and 3.31 s total time per trial respectively, averaged across measurements taken by two independent observers): the pattern of looking times was consistent with that of overall time on task.

Overall, these results provide qualified support for the use of static time on task as a predictor of distraction, but suggest that it needs to be augmented with other indices that can be used early in the design process. Examples include measures of how the driver holds the device while driving (as it affects steering and glance patterns) and measures of task interruptability (Monk and Kidd, 2007; Noy et al., 2004). However, research is required to determine optimal combination of predictors for a broad variety of in-vehicle tasks.

Acknowledgements

Auto21 Network Centres of Excellence, the Canadian Foundation for Innovation, and Ontario Innovation Trust funded this research. We would also like to thank David Wilson, Anne Almey, Ryan Toxopeus, and Lauren Meegan for their help with the study.

References


Please cite this article in press as: Reed-Jones, J., et al., Testing assumptions implicit in the use of the 15-second rule as an early predictor of whether an in-vehicle device produces unacceptable levels of distraction, Accid. Anal. Prev. (2007), doi:10.1016/j.aap.2007.08.018


