Acceptable distraction? Evaluating the effects of in-vehicle technologies on driving

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ABSTRACT
The number of new in-vehicle devices is increasing and techniques must be developed to ensure that these devices do not produce unacceptable levels of distraction. Ideally these techniques should be quick and easy to use and applicable early in the design process. One approach is to use the time required to use the device (static time on task) to decide whether a device produces unacceptable levels of distraction (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 periodic hazards; 3) Time on task predicts perceived distraction, collisions, and driving errors. This study was designed to test these assumptions by comparing two in-vehicle tasks, one relatively safe (radio manipulation) and other relatively dangerous (dialing a hand held cellular phone). Thirty-two participants were tested in a driving simulator. Static time on task underestimated dynamic time on task, though the difference between the radio and cellular tasks were roughly consistent across testing conditions (with the cellular task taking more time). Participants who expected hazards had slightly longer time on task than those that did not, but the effect was only marginal (p = .09) and consistent across tasks. Finally, the task 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.
INTRODUCTION

From cruise control to route navigation systems, from crash detection sensors to in-vehicle entertainment systems, the number of in-vehicle technologies is increasing. Although some of these systems may prove beneficial, some have the potential to distract, which is a serious problem given inattention/distraction played a role in up to 78% of the crashes in a recent naturalistic investigation (1). Collision data have prompted the development of guidelines such as the EU Statement of Principles (2), the HMI Checklist (3) and the British Standard Design Guidelines (4), but determining what constitutes an acceptable level of distraction is not an easy task. Methods for measuring distraction and standards for determining what constitutes an unacceptable level of distraction must be developed - preferably before crash data accumulate (5, 6). To be maximally useful these methods should be applicable early in the design process, before substantial amounts of money have gone into product development, and they should be versatile, inexpensive, and easy to use. This explains the appeal of absolute standards such as SAE Recommended Practice J2364: “the 15-second rule” (7, 8), 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 in this study these assumptions are tested using a relative approach, comparing tasks that are commonly considered safe and dangerous in terms of static and dynamic time on task, perceived distraction, and driving performance.

There are a number of theories relevant to the issue of multi-tasking in vehicles, 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. These theories suggest that a variety of different types of interference contribute to overall distraction. For example, according to Baddeley’s theory (9) interference occurs when driving and a secondary task tap the same specific working memory resource (the phonological loop, the visual-spatial sketchpad, or the central executive). According to Wickens (10), interference occurs when tasks share common processing stages (early perceptual vs. late central processing), modality (auditory vs. visual), or response type (spatial vs. verbal). There have even been recent attempts to model multi-task interference for specific devices (11-13). However, at this point the models are not so well developed that they can predict whether any arbitrary device would produce unacceptable amounts of distraction. That is because the question of what constitutes “acceptable” is in itself problematic.

Generally speaking, there are 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. Otherwise the device is deemed acceptable. One problem with this approach is that it relies on choosing an acceptable comparison task, and this choice can engender considerable debate (14, 15). 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 (1). Some are necessary, some are inevitable (given human nature), and some are even beneficial, as occurs when carrying out a secondary activity helps drivers stay alert (16). 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 trying to read a map while driving. Thus, when evaluating the distraction produced by route guidance system it might be
important to consider the distraction produced by reading a map. 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.

Another approach is to use comparison tasks based on devices that are already in vehicles, such as the radio and climate controls. These devices seem to be considered safe – at least based on legal precedent (using these devices has not yet been made illegal). Furthermore, there is already research on interference produced by these devices (17). Nonetheless, there are complications with this approach as well. The spatial layout of controls can vary considerably from vehicle to vehicle, as can the activities involved in using these devices. There is more than one way to use a radio, for example. Some radio tasks are more demanding than others. Thus, when designing an experiment, the choice of what to make the “standard” radio comparison task can be fraught with controversy 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 could be found for any arbitrary new in-vehicle technology with an already existing in-vehicle device. Devices may interfere in a variety of different ways and it can be difficult to predict what type of interference a given device will produce. 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 absolute standards is understandable. For example, SAE ‘15 second rule’ uses the criterion of 15 seconds static time on task to distinguish between devices that produce acceptable and unacceptable levels of distraction (7, 18). Specifically, a device is deemed acceptable if interacting with the interface requires fewer than 15 seconds for 8 of 10 experienced drivers who range in age between 45 and 60 years. Otherwise, the device is deemed unacceptable. Although this method was initially designed for route guidance systems, some suggest that it could be extended to other devices (19, 20). This technique is not without problems. For example, it does not take into account how interruptible the task is (21).

Nonetheless, it has the advantage of being 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, the use of relative standards typically requires 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 seconds) was based on the judgments from expert panel that agreed that most in-vehicle tasks take less than 15 seconds to complete (7). The use of static time on task to predict behaviour in a moving vehicle assumes that tasks that take around 15 seconds in a static vehicle will take 15 seconds for a driver 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 crash risk should increase with time on task (22). Thus, as static time on task increases, so should the number of collisions and driving errors, such as lane deviations and prolonged hazard response times (23).
In this study, these assumptions were tested. To begin, consider the distraction created by driver interaction with a device interface, an important factor in device usability (24). Two devices were compared: one thought to be risky and another thought to be safe. The risky task was dialing a hand-held cellular phone while driving, a practice that is now illegal in some jurisdictions (25). The dangers of conversing on cellular phones while driving are well documented (1, 26-29) and some contend that the risks faced when driving while talking on a cellular phone are comparable to those driving while intoxicated (30). These studies typically find little difference between hand-held and hands-free cellular phones (31). However, in this study the interest was not in conversing on a cellular phone but rather dialing a cellular phone, a task that might be expected to produce visual-spatial, motor, and cognitive interference. Drivers perceive that dialing a hand held phone is more distracting than using a hands-free model (32) and effects have been shown in lane keeping and hazard detection (33,34). In this study, participants were required to dial an 11 digit number that was familiar to them, as they might if they were dialing friends or family on the way home. This task was chosen because it did not require the presentation of an arbitrary number for the participant to dial (which in itself might cause cognitive interference).

For the “safe” task, radio manipulation was chosen. Radio tasks are often used as safe comparison for visual-manual tasks (14, 34). There is a variety of radio tasks in the literature as well as a variety of types of radio (21, 34). The demands of the task may vary depending on the specific layout and tasks. However, in this study the task did not involve having to learn lists of new numbers (which in itself might produce distraction). It used the standard vehicle radio built into the driving simulator where the testing took place. In the interests of having a strong enough manipulation to find some effects on performance, a moderately difficult version of the task was chosen. Participants were required to eject a tape, push three pre-set buttons on the radio (as if scanning the alternatives), and then push the tape back in, as would occur if none of the alternatives were acceptable.

It was impossible to equate the safe and risky tasks perfectly. However, given that the goal of this study was not simple task comparison, this was deemed adequate. Instead, the goal was to investigate the consistency between static time on task and other indices in terms of how the two tasks were evaluated: specifically, if the task that produced more distraction based on static time on task had higher dynamic time on task; if the task that produced higher dynamic time on task in a hazard-free environment also produced higher time on task when drivers were lead to expect hazards; and if tasks that were judged to be more dangerous based on static and dynamic time on task also produced 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 differences between the two tasks should be consistent, whether it is static, dynamic (hazard free), or dynamic (hazard filled) time on task. Similarly, the task that is judged to be the most dangerous based on static time on task should also produce more perceived distraction and more collisions and driving errors.

METHODS

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 task. Half the participants 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 subject.

In Experiment 1b, a different group of drivers were 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. As well, collisions and hazard response times were measured. Driving performance was measured in three conditions: radio (driving while manipulating the radio controls), cellular (driving while dialing 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.

Participants

Thirty-two licensed drivers participated (16 each in Experiments 1a and 1b). Participants were recruited through the undergraduate participant pool at the University of Guelph. In each study there were 9 women and 7 men. All were right-handed and between the ages of 17 and 21 years (mean age = 19.0 years and 19.3 years in Experiments 1a and 1b respectively). The 32 participants were all unfamiliar with the specific model of cellular phone employed in the study but 18/32 reported using some type of cellular phone while driving.

Apparatus and Materials

In-Vehicle Devices

The radio used was a standard equipped Saturn radio with tape deck and the following features: LCD display screen, a rotary dial for power and volume, a push button eject for the tape, 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 (1 in. = 2.54 cm). The cellular phone was a Nokia 6188. Although this phone had the potential for hands-free operation, it was used solely in its hand-held mode. The cellular phone console was 14 cm down and 33 cm to the right of the line of sight.

Simulator

A Drive Safety DS-600c fixed base driving simulator was used in testing. This simulator involves a Saturn four-door sedan equipped with all standard vehicle controls, augmented with audio and vibration transducers and force feedback to provide a reasonably realistic driving experience. Image generation computers projected the simulation through LCD display systems onto six seven-foot projection screens that provided a 300° wrap-around virtual environment (250° in front and 50° in the rear).
Stimuli

The virtual environments were designed to simulate driving through an industrial park on a sunny day. The simulated road represented a paved surface with a single lane each way and no median. There were no sidewalks but road shoulders were wide enough to accommodate a parked vehicle and individual vehicles were parked at random intervals (averaging 2.5 vehicles per km: 1 mi = 1.61 km). There was light ambient traffic that obeyed all of the rules of the road and did not interfere with the task or hazard events (on average 3.5 vehicles per km). All areas of the simulation had randomly placed pedestrians and cyclists on the sides of the road as well as parked cars and trucks.

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-meter, 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 measured 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 cyclist) 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. Hedgerows 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 seconds 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 breaking distance at 70 km/h is ~57 m. (35). At this speed, a 3.5 second 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 seconds after the beginning of prompted tasks. The simulator initiated tasks that occurred with a collision hazard in the same way as tasks that occurred without a collision hazard, and consequently it was difficult for participants to predict when the hazards would emerge.

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

Questionnaire

In the questionnaire, the amount of perceived interference for each secondary task was measured using a 1 to 6 rating scale, in which 1 indicated “Had no noticeable effect on the driving task” and 6 indicated “Had a noticeable effect on the driving task – making it almost impossible”.
Procedure

At the start of the study a research assistant administered a pre-screening questionnaire to test for predispositions to simulator adaptation syndrome (36). The assistant told participants how the simulator worked and gave the following directions:

Throughout the study you are to attempt to drive on average at 70 km/h, which is the speed limit for the “world”. In addition, the car can handle taking the curves at this speed but in the beginning you may wish to slow down until you get used to how the simulator feels in the turns. If you continuously speed during this study, it will be terminated and the data collected from your participation will be thrown out. You are expected to follow all “real world” traffic regulations. You are to navigate the route by following the road because there will be no intersections to deal with.

Participants were instructed to depress the brake and come to a complete stop, even if completing a secondary task, if they encountered a hazard. They were also told that if they should encounter an obstacle while dialing a phone or manipulating the radio, they should stop first, finish dialing or manipulating, and then drive around any obstacle in their path in a safe manner, returning to 70 km/h as soon as feasible.

As soon as the participant understood how to drive through the virtual environment, the research assistant gave the instructions for each secondary task. The radio manipulation task was explained as follows:

When the simulator voice indicates “begin radio task” followed by a tone, you are to turn the radio on, eject the tape and leave it in the cradle, tune through any three station presets, reinsert the tape, turn the radio off, return both hands to the wheel and report out loud “stop” to indicate you have completed the task.

The instructions for the cellular task were as follows:

When the simulator voice indicates “begin cellular task” followed by a tone, you are to pick up the phone from the center of the dashboard, dial any 11 digit number you are familiar with, depress the send key, hold the phone to your ear, wait 1 second, depress the end key, return the phone to the center console, return both their hands to the wheel, and report out loud “stop” to indicate you have completed the task.

Once participants understood the instructions, they drove through 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 then drove the test courses, each of which took from 8 to 12 minutes to complete. In Experiment 1a, participants drove two courses and time on task was measured in static and dynamic conditions when there were no hazard trials. In Experiment 1b, participants drove all five test courses and had time on task, lane deviations, collisions and hazard response
RESULTS

This study was designed to test three assumptions: 1) The assumption that static time on task could predict dynamic time on task for a driver in a moving vehicle; 2) The assumption that time on task as measured in a relatively hazard-free environment could be used to predict time on task in a situation where drivers expect hazards; and 3) The assumption that time on task predicts perceived distraction, collisions and driving errors.

To test the first assumption, an analysis was conducted with data from Experiment 1a. 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 from the signaling to the participant to begin the secondary task (dialing a cellular phone or manipulating a radio) to when the participant said, “stop” (at which time the research assistant pressed a button). As can be seen from Figure 1, time on task was longer for the cellular than radio task (mean difference = 2.36 seconds, F (1,15) = 69.448, p < .001, partial $\eta^2 = .822$) and longer in the dynamic than static conditions (mean difference = 3.67 seconds, F (1, 15) = 181.749, p < .001, partial $\eta^2 = .924$). However, there was no interaction between task and testing conditions, indicating that the magnitude of the difference between two tasks was about the same in static and dynamic conditions.

FIGURE 1. Mean time on task for radio and cellular tasks under static, dynamic hazard-free, and dynamic hazard-filled filled testing conditions (Standard error bars included).

Overall time on task decreased from the first five to last five trials by approximately 0.61 seconds (F (1,15) = 20.682, p < .001, partial $\eta^2 = .580$). There was also a three-way interaction
between the type of test, task and trial \((F(1,15) = 5.17, p = .038, \text{ partial } \eta^2 = .256)\), such that the decrease in time on task from the first to last set of five trials was larger for the dynamic radio condition than the other conditions \((M = 0.97 \text{} \text{seconds as opposed to 0.50 seconds for the dynamic cellular, 0.62 for the static radio, and 0.68 for the static cellular conditions})\). There were no other significant effects.

A second set of analyses was conducted to find out if time on task in a hazard-free environment (Experiment 1a) predicted time on task in an environment where drivers expected hazards (Experiments 1b). For this analysis there were three factors: testing conditions (hazard-free and hazard-filled), task condition (radio, cellular), and trial group (first five, last five). Results are presented in Figure 1. Average dynamic time on task was 1.29 seconds less in the hazard-free conditions than it was in hazard-filled conditions but the difference was only marginally significant \((F(1,30) = 3.11, p = .088, \text{ partial } \eta^2 = .094)\). As before, time on task was significantly higher for the cellular than radio task \((F(1,30) = 74.68, p < .001, \text{ partial } \eta^2 = .713)\) and time on task for the first five trials was significantly higher than for the last \((F(1,30) = 13.49, p = .001, \text{ partial } \eta^2 = .310)\). The drop in time on task from the first to last five trials was greater for the radio task than the cellular task (mean reduction in time between the first and last trials was 0.88 seconds as compared to 0.38 seconds for the radio and cellular tasks respectively: \(F(1,30) = 4.42, p = .044, \text{ partial } \eta^2 = .128)\). There were no other significant effects.

The final analyses were performed to determine whether time on task was related to other indices of distraction. As predicted, the cellular phone task (the one that required greater time on task) had significantly higher perceived interference ratings \((F(1,15) = 5.382, p = .035, \text{ partial } \eta^2 = .264)\). Ratings of perceived interference 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 \((F(4,60) = 1.288, p = .285)\). There was also no interaction between task and course \((F(4,60) = 0.5, p = .677)\) see Figure 2.

It was also predicted that the task with the highest time on task would also produce the most lane deviations, collisions, and hazard response times. Performance was compared between the radio, cellular, and baseline driving conditions. However, to ensure drivers did not engage in compensatory slowing while carrying out the radio and cellular tasks, preliminary analyses were carried out comparing average velocity measured in kilometers per hour \((1 \text{} \text{km} = 0.62 \text{} \text{mi})\) 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 faster when performing secondary tasks \((F(2,30) = 3.57, p = .041, \text{ partial } \eta^2 = .192)\), though the differences in speed were minimal \((M = 70.32, 70.23, \text{ and } 69.29 \text{} \text{km/h for the radio, cellular, and baseline conditions respectively})\).

Lane deviations were counted as the number of times during a trial that the participant’s vehicles wheels 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, \(F(2,30) = 18.384, p < .001, \text{ partial } \eta^2 = .551)\). As can be seen from Figure 3, 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 dialing \((33, 34)\) but not the effects of cellular conversation \((27)\).
It was also predicted that the more time consuming task would also 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). As can be seen from Figure 3, this prediction was not supported. Although there were no significant differences between the three conditions in the number of collisions ($F(2,30) = 1.703, p = .199$, partial $\eta^2 = .102$), the trend was toward more collisions in the radio condition rather than the cellular phone conditions (nine as compared to four and three in the cellular phone and baseline conditions respectively).

Hazard response time was recorded as the amount of time between when an entity entered the path of the vehicle when the brake pedal was depressed, see Figure 3. Task had a significant effect on hazard response time ($F(2, 30) = 4.56, p = .019$, partial $\eta^2 = .23$). LSD post-hoc comparison revealed that response times were significantly higher in the radio than baseline conditions ($p = .005$) though the difference between the cellular and baseline conditions was only marginal ($p = .054$). There was no significant difference between the cellular and radio tasks, though the trend was in the opposite direction as was predicted, with radio tasks having higher response times. Despite repeated hazards, hazard response times did not decrease significantly from the first to last five trials (mean difference = .02 seconds). There was no significant interaction between task and trial.

FIGURE 2. Mean perceived distraction ratings for the two tasks from the first to last driving course (Standard error bars included).
FIGURE 3. Driving performance: Lane deviations, collisions, and hazard response time (Standard error bars included).

CONCLUSIONS

The use of static time on task to determine whether a device produces unacceptable distraction is based on three assumptions. Overall, the results of this study offered qualified support for the first and second of these assumptions. Differences between the safe (radio) and dangerous (cellular phone) tasks were apparent regardless of how time on task was measured (static, dynamic hazard-free, dynamic hazard-filled). However, time on task measurements taken in static-hazard-free environments underestimate the time on task in two ways: by underestimating the effect of having to coordinate the task with driving (by about 4 seconds in this study), and underestimating the effect that expectations of hazards will produce (which added another 1.29 seconds in this study). For this reason, even though most tasks take less than 15 seconds (7), it might be safer to lower the criterion 10 seconds if time on task is measured in a static vehicle.

The support for the third assumption was not as uniform. The task judged most time consuming based on static time on task (cellular phone dialing) produced higher perceived distraction ratings and more lane deviations, as predicted. However, the results were not in the hypothesized direction when it came to collisions and hazard response time, where the differences between conditions were not as apparent, and if anything, the cellular task produced better performance. Although the inconsistency between lane keeping and response to hazards in front of the vehicle is consistent with accounts that discriminate between the roles of ambient and focal vision (10) for lane keeping and focal hazard detection respectively, the pattern of results was not quite as predicted. Higher hazard response times and collisions were to be

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expected in the radio condition, where participants were forced to look down to the radio console (which would presumably compromise focal vision but leave ambient relatively unaffected). Visual factors cannot be the sole explanation though, because the research assistants observed that in the cellular condition most drivers dialed while balancing the phone on the steering wheel (vision was not impeded), and yet there were more lane deviations. This may be because balancing the phone in this way increases manual demands on steering. This would have the effect of increasing the number of lane deviations and, if the participants were aware of this problem, increasing perceived distraction.

Overall, the results provide some support for the use of static time on task as an early index, but suggest the need for new techniques that can be used early in design process to distinguish between devices that produce acceptable and unacceptable amounts of distraction.

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