ABSTRACT

Electronic navigational systems allow drivers to receive travel directions while driving, rather than preplanning a route. This additional attentional load on drivers might prove to be hazardous -- particularly for older adults who have greater difficulties multitasking and switching their attention between different parts of the visual field. A driving simulator was used to evaluate the perception time to critical events in the presence and absence of a navigation system with young (n=18, age=18.8 years SD=0.7 years) and older drivers (n=15, age=73.1 years, SD=6.1 years). The results of this study indicated that though older drivers were slower to react to critical events, and both groups were faster to react to pedestrian incursions than sudden light changes, messages from the travel system did not interfere significantly with perception reaction time in either group.

INTRODUCTION

Traditionally, there were two methods for finding the way to unfamiliar destinations while driving. Drivers could look for cues in the environment (e.g. signs, landmarks) or they could use a map. Both techniques have limitations. Signs and landmarks are not always available, and the ones that are may be inaccurate. However, purchasing and storing maps for every possible destination is expensive and wasteful, especially given that drivers may only go to a given destination once. Furthermore, using either method can be stressful, especially in the face of heavy traffic and unexpected impasses due to construction and vehicle crashes.

As a result, technologies have been developed to make it easier to follow travel directions while driving. Onboard electronic navigation systems can utilize GPS (global positioning system) information and computerized map databases to guide drivers along unfamiliar routes. Such electronic navigation systems have several advantages over the traditional techniques. For example, users do not need to determine their current position on the map, as the GPS system can typically locate them within a meter. Similarly, electronic navigation systems can readily provide new routes whenever the originally planned routes turn out to be unfeasible. Consequently, many drivers are now opting to install onboard electronic navigation systems.

Although there are many types of electronic navigation systems, a typical system will use sound, a visual display and a keypad [6]. During a few seconds of driving, a driver might receive the auditory note “At the next intersection, turn left” while a graphical representation of the intersection, an indicator of the distance until the intersection and the name of the intersecting streets might appear on the screen. Should the driver be unable to make the turn, the driver might have to press a “reroute” key.

However, using these devices while driving requires carrying out several activities at once [4]. By its nature, driving an automobile requires multitasking: maintaining velocity, checking to ensure the roadway is clear, ensuring the traffic light is green, negotiating curves, etc. Nonetheless, there are limits to our ability to multi-task. Multiple-resource theory suggests that we have limited resources that we can allocate to different sensory, motor, and cognitive tasks [14]. As it turns out, driving requires a variety of sensory, motor, and cognitive functions, and excessive demands on any one system may have deleterious effects on driving performance. One risk is the cognitive (attentional) load imposed by carrying out attention-demanding secondary tasks. When drivers are asked to divert a part of their attention to a secondary task, they lose their ability to maintain a constant velocity [11]. Similarly, when drivers are distracted the probability of a vehicle crash increases markedly [15]. This effect has been noted with many attention-demanding devices, including cell phones [13]. Electronic navigation systems may also serve to divert attention, and thus it is important to assess the impact of these systems on driving performance.
There is an additional complication. With the demographic transition, there are increasing numbers of older drivers on the road. Older drivers face challenges that younger drivers do not face. With age there are a variety of changes in sensory and motor function that make it difficult for older drivers to respond as quickly to events in driving environment. Additionally, even when sensory and motor factors are controlled, older adults have more difficulty multi-tasking [8, 3]. There are also well-documented age-related decrements in a variety of other attentional abilities [10, 12], including visual search (looking for desired items such as signs and landmarks in a visual scene) and orienting (noticing important events in the world, such as oncoming hazards). Electronic navigational systems may prove to be especially beneficial for older drivers, given their difficulties with visual search and their problems carrying out secondary tasks (such as reading maps while driving). At the same time, it is also possible that these devices might put older drivers at risk. Older drivers represent an increasing proportion of the driving public and consequently, it is especially important to test these technologies on older drivers.

In this first investigation, we decided to look at the impact of an electronic navigation system as it relates to orienting. Orienting involves redirecting the focus of attention to locations in the visual field where important information is presented, so that responses can be made quickly and accurately. There are several types of orienting [1]. One, called endogenous orienting, involves deliberately moving the attentional focus to locations in the visual scene where important information is expected to appear (for example, the traffic lights at an intersection). The second type of orienting is not controlled by deliberate intentions, but is rather driven by stimuli in the environment. Thus, exogenous orienting occurs when the attentional focus is redirected in response to stimuli in unexpected locations, for example, as occurs when a child runs out from behind a parked car. Both types of orienting are necessary for driving. There is reason to expect that the cognitive demands of using an in-vehicle navigation system might have deleterious effects on orienting especially for older drivers, who show a reduction in the size of the area in the display that they can pay attention to (the useful field of view) when they are carrying out secondary tasks [9].

Thus, we looked at participants’ ability to react to unexpected events in either expected or unexpected locations. For the unexpected event at an expected location, we measured reactions to a sudden light change from green to red. For the unexpected event at an unexpected location, we measured reactions to a pedestrian or animal suddenly veering into the path of the vehicle. For both, perception response time was measured: the time between the event (when the light change or lane incursion) and when the foot was lifted from the gas pedal.

We tested the participants in two conditions. In one, there was a travel information system that provided messages about where and when to turn. In the second, participants had to determine where to and when to turn by looking at the road (some roads were barricaded). In this way, we tried to produce some of the conditions experienced by drivers trying to find their way by looking for cues in the visual environment (a more appropriate control than having drivers negotiate a familiar road for which they did not require directions). As well, in this way we could have participants in both conditions navigate the same route.

We predicted that participants would take longer to respond to unexpected events when using the travel information system and this difference would be especially apparent when participants were responding to unexpected events in unexpected locations [7]. We predicted that this difference would be especially pronounced among older drivers.

**METHOD**

The driving simulator consisted of a color computer screen (ViewSonic), gas and brake pedals (Logitech), and a steering wheel (Logitech). Participants sat on an office chair in front of the screen and pedals, such that their eyes were one meter away from the screen, making the screen occupy 22.78˚ of visual angle. The simulator ran DriveSafety’s Vection Simulation Software.

**PARTICIPANTS**

All participants had their permanent license and at least 2 years of driving experience. As well, all were required to pass a screening test designed to measure whether an individual had a propensity to Simulator Adaptation Syndrome. This test alerted us to individuals with predictors of Simulator Adaptation Syndrome: a propensity to motion sickness, balance problems, problems with claustrophobia, migraines, diabetes or irregular blood sugar, etc. The individuals who did not pass the screening test were directed to experiments that did not involve the driving simulator.

Twenty-five older adults (7 men, 18 women, average age = 74.2 years, SD = 5.3) and 25 younger adults (4 men and 21 women, mean age = 18.3, SD = 7 years) passed the screening test. The older adults were healthy, active seniors from a local recreational centre whose performance on the Standardized Mini-Mental State Examination indicated no cognitive impairments (M = 28/30). As well, all older adults had better than 20/40 acuity, as measured by the Early Treatment of Diabetic Retinopathy acuity test. The younger adults were university students from the University of Guelph participant pool.
At the end of the study, older participants were given University of Guelph pin in appreciation for their participation. Students were awarded a participation credit towards their first year psychology course requirements.

**PROCEDURES**

Participants were asked to answer questions for Simulation Adaptation Syndrome pre-screening test either by telephone or e-mail before the study began. After arriving at the laboratory, participants were briefed on the functioning of the simulator, how to set the car in gear, how the pedals worked and where their view mirrors were, etc. They were then invited to drive through the three practice scenarios.

The first practice scenario was a straight stretch of road with numerous stop signs and varying speed limits, ranging from 20km/h to 80km/h, in which participants got used to stopping as well as maintaining a constant speed. The scenario was set in the countryside and was designed to take approximately 6 minutes to drive through. The second practice scenario was a series of intersections with either stop signs or traffic lights, in which participants practiced negotiating turns and dealing with minimal traffic. The scenario was set in a suburban environment and was designed to take approximately 5 minutes. The third scenario was a series of intersections with traffic lights. In this condition, the computer gave travel directions. Roads that were not requested by the computer were blocked off using traffic barricades. The purpose of the scenario was to accustom participants to what the experimental scenarios would be like. This scenario, which included events requiring braking reactions, was set in an urban environment and was designed to take approximately 4.5 minutes.

Upon completion of the practice scenarios, the participants were given a 5-minute break, after which they were invited to complete the four experimental scenarios. For the experimental scenarios, participants were asked to drive as well as they could, following traffic signs and avoiding crashes.

The four experimental scenarios were designed to measure perception time to two types of unexpected events. Pedestrians and animals crossing the street were truly unexpected events, because they occurred at unexpected times and at unexpected locations. At the time when the pedestrians would begin to cross the road, they would occupy 1.38˚ of visual angle. Traffic lights turning from green to red, skipping the yellow indicator, were also unexpected events, because although one knew where to look when approaching an intersection, the lack of the yellow warning light made the red light unexpected in time. In both cases, the events were programmed to happen at a 15-meter distance away from the beginning of the intersection, at which point the red semaphore has a diameter of 0.35˚ visual angle. For example, the traffic lights would turn red only moments before entering the intersection. The scenarios were set in an urban environment and were each made up of an equal number of turns. Each scenario was designed to take 4.5 minutes.

Two of the experimental scenarios had travel directions administered by our navigation system and the other two simply had the navigation system turned off, so as to create a balanced design between baseline and experimental treatment conditions. In navigation system condition, an arrow (2.2˚ visual angle in width) would appear at 2.3˚ visual angle from top of the computer screen, 10 meters prior to the intersection, to indicate whether a turn was required or the participant should go straight at the upcoming intersection. This simulated a head-up display, which is available in electronic navigation systems where the graphical display is projected onto the windshield. A prerecorded voice would also indicate which direction to take, such as by saying “Please turn left at the next intersection”. Aside from this manipulation, the scenarios were otherwise equivalent in all aspects. In the control conditions, the routes were identical except the participant knew in which direction to travel because the two invalid directions were barricaded, resulting in intersections with only one possible way through. The order of the navigation and control conditions was blocked and counterbalanced. The order of the different types of critical event (unexpected events in expected or unexpected locations) was randomized across each block.

**RESULTS**

There were three factors: driver age (young vs. older adults), condition (travel navigation, control) and type of unexpected event (unexpected light change, pedestrian/animal incursion). Thus, the experiment had a split plot design. Age was the between subjects factor and condition and type of unexpected event were within subjects factors. A mixed ANOVA ( = .05) was used to analyze the effects of the independent variables on hazard perception time.

The most reliable means of measuring hazard perception time is to measure how long it takes for the driver to release the gas pedal following the occurrence of a critical event. Because drivers also had to maintain a constant velocity, they would occasionally have their foot off the accelerator pedal when an event occurred. As a result, it was not always possible to calculate the perception time for certain critical events. Also, we removed perception times shorter than 100ms and longer than 1500ms, as these were likely to be due to a coincidence in pedal release and were not a successful detection. Finally, we removed the data from any participant who did not have a minimum of one data...
The effects of the presence of a travel navigation system, driver’s age and event location expectancy on perception time.

**CONCLUSION**

We predicted that participants would require significantly more time to perceive a critical event when using a navigation system based on the literature on cell phones [13]. Our results did not fulfill our expectations. In fact, if anything the trend was in the opposite direction to our prediction, with faster perception times in the navigation condition, though the effect was not statistically reliable. From the perspective of multiple resource theory, this might imply that the driving and listening to the messages from navigational systems require different types of resources. It is also possible that drivers, with minimal attentional load, absorb information from travel navigation systems passively. Navigation systems may not produce the same amount of interference as cell phones. This may be because drivers do not have to respond back to navigation systems or reflect on topics extraneous to the driving task.

We also found that although perception times were longer for older drivers, there was no significant interaction between experimental condition and age, which suggests that the response to the navigation system was comparable for older and younger drivers in this study. If this result holds under different testing conditions, this is an encouraging finding for those designing navigational systems. It shows that older and younger drivers alike can benefit from the inclusion of these systems in cars.

**LIMITATIONS**

Our study shows that listening to directions from a navigation system did not impede perception time -- at least as compared to a situation in which participants had to look around the driving scene to find cues for where they should drive. However, using a navigation system involves more than listening to travel directions. It is possible that the most attention-demanding aspects of the task are entering travel destinations and adjusting the system when there is a need to plot a second route (as occurs when traffic is diverted due to an accident). Also, it is important to recall that hazard perception time is only one aspect of driving performance. Finally, it is possible that researchers using different control tasks would find different results. As it turned out, determining where to go when barricades blocked all but one road proved to be surprisingly difficult.

More research is necessary. In particular, it is important that the study be replicated using a real car and instrument panel, and a viewing screen with a wider field of view. The present study involved a single channel system with a gaming steering wheel, making the testing environment artificial. The study also needs to be replicated using additional indices, including measures of increased brake pressure and the onset of motor movement.

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**REFERENCES**


CONTACT

Pierre Desroches is currently a candidate for a Masters of Arts degree in Applied Cognitive Science (Psychology) at the University Guelph. He may be contacted using: pierre@uoguelph.ca