Older Users and In-Vehicle Navigation Map Design Elements

Crystal Tobias
San Jose State University
San Jose, CA 95192, USA

Volkswagen Group of America
Electronics Research Laboratory
Belmont, CA 94002, USA
Crystal.Tobias@vw.com

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Abstract
This study investigated digital map reading performances of older and younger participants across map concepts. Participants answered questions related to their map reading while driving in a simulator. Mixed ANOVA analyses were completed on the dependent variables: response time, self-reported difficulty, and eye glance behavior. There was a significant difference in response time, with older participants requiring longer time to respond. Although no significant differences were found for eye glance duration towards the map, there were significant differences for the number of eye glances toward the maps with older participants glancing at the maps twice as often as younger participants. Younger participants had significantly longer glance durations towards the driving scene. It is suggested that the higher number of glances reflects the older participants' need to retain the information in working memory. This proves useful in better understanding the cognitive and visual processes of older drivers while reading digital maps.

Author Keywords
In-vehicle navigation; digital maps; older drivers; eye glance behavior

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

Introduction
Digital maps are becoming more available and the go-to for drivers' navigational needs. These digital maps are available on the web (e.g., Google Maps), on smartphones (e.g., apps), and in-vehicle infotainment systems. Additionally, many users use these navigation applications while driving, so digital map use for navigating in the car is not exclusive to built-in systems. Users of all ages use digital maps, but that does not mean that all users have the same needs to use the maps efficiently. Various declines, including cognitive and visual decline, associated with aging have been documented in the literature (e.g., Davidse, 2006; Kline, Kline, Fozard, Kosnik, Schieber, & Sekuler, 1992). Because digital maps require the use of cognitive and visual resources, older users are susceptible to poor performance using digital maps despite their frequent exposure to them. In parallel, the number of older drivers is increasing (Owsley, Ball, Sloane, Roenker, & Bruni, 1991; Ziefle, Pappachan, Jakobs, & Wallentowitz, 2008). In 2012, 40 million drivers were over the age of 65 (AAA & The Institute of Mobility, Activity and Participation at the University of Florida, 2013); this was over a 21% increase from 2002 (National Highway Traffic Safety Administration, 2014). Thus, the older population is an important and growing segment of drivers on the roads. As digital maps become a staple for driver's navigational needs, it becomes important to not only improve the general usability of the navigational map, but to ensure it matches the needs of older drivers.

This study investigated the usability of vehicle navigation map concepts using both younger and older participants to better understand which map promotes better map reading performance and how age may impact this performance. These maps were designed for future implementation in the next in-vehicle infotainment system at Volkswagen Group of America. Since the purpose of this study was to learn how well participants could read the maps, audio navigation is not considered. All participants drove in a driving simulator and were required to interpret different maps. Response time, accuracy of map interpretations, self-reported difficulty, and eye behavior were the main dependent variables measured.

Background
Older drivers will encounter the natural decline of cognitive and visual ability (Charness & Boot, 2009; Kline, Kline, Fozard, Kosnik, Schieber, & Sekuler, 1992; Ratcliff, Thapar, & McKoon, 2001; Salthouse, Atkinson, & Berish, 2003). Older individuals are likely to have decreased information-processing speed, limited functionality of working memory and executive function, and issues with selective attention (Davidse, 2006; Deary, et al., 2009; Owsley, Ball, Sloane, Roenker, & Bruni, 1991; Salthouse, Atkinson, & Berish, 2003). These cognitive challenges can translate to degraded performance, such as slower response times, decreased capabilities to process multiple pieces of information in parallel, decreased capabilities in planning and executing action, and deteriorated abilities to inhibit distractors (unnecessary information) and focus on relevant stimuli (Davidse, 2006; Pick, 2010; Green & Williams, 1992). Anstey and Wood (2011) conducted an on-road driving test using older drivers. They found that impairments in information

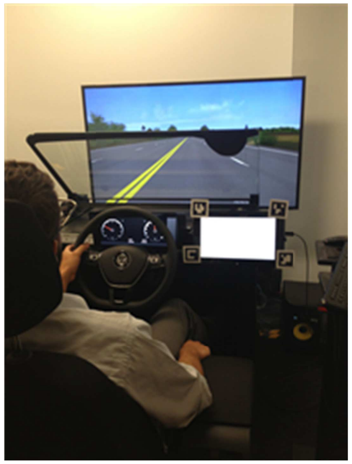

Figure 1: This image represents the set up of the stationary driving simulator used in the study. The maps were shown on a Sony Vaio Duo 11 (note the white rectangle), which was mounted in a location similar to that of current in-vehicle infotainment systems.

processing, attention, task switching, and other cognitive processes were strongly related to poorer driving performance, as indicated by errors in lane keeping, acceleration, and braking (Anstley & Wood, 2011).

Apart from cognitive decline, older individuals also suffer from a decline in the visual system. As people age, individuals become vulnerable to vision problems, including presbyopia, difficulties differentiating similar colors and hues, limited visual field and useful field of view, limited acuity, and sensitivity to glare (Boisgontier, Olivier, Chenu, & Nougier, 2012; Davidse, 2006; Kline, Kline, Fozard, Kosnik, Schieber, & Sekuler, 1992; Owsley, Ball, Sloane, Roenker, & Bruni, 1991).

Aging also causes other perceptual and cognitive impairments. The combined impairments in perception and information processing hinder older adults in their ability to attend to relevant information, encode and understand the information, and then know the next set of appropriate actions (Davidse, 2006). Consequently, objects in the world may not be perceived well, or at all, due to the impaired processing of object perception. Older adults find visual search tasks more challenging than do younger adults. Aksan and her colleagues (2013) found older drivers were less likely than younger drivers to identify landmarks in a naturalistic driving task, even if the general location and landmarks were familiar to them. Although older drivers could have used crystalized knowledge to compensate for the demanding nature of the visual search task, it was not enough to overcome task difficulty.

In addition to these decreased abilities in general cognitive and visual processes, aging also affects processes with visuospatial cognition (Jenkins, Myerson, Joerding, & Hale, 2000; Iachini, Poderico, Ruggiero, & Iavarone, 2005; Kostyniuk, Streff, & Eby, 1997). People specifically use visuo-spatial memory for map learning (Coluccia, Bosco, & Brandimonte, 2007). As drivers age and face a reduction in visuo-spatial cognitive capability, they have higher chances to incorrectly judge the location of landmarks and their current position (Pick, 2010). In other words, drivers have greater difficulty with way-finding (correctly identifying and understanding the spatial locations of one's self and of targets along a route). This could partly explain why older drivers performed worse with the landmark identification task found in Aksan's research (Aksan, et al., 2013). Kostyniuk, Streff, and Eby (1997) comment that a substantial amount of literature supports the link between decreased spatial ability and decreased navigational competency in older adults.

When using navigation systems, older adults have been shown to have significantly longer glance times (often longer than 2.5 seconds) and to change their driving speed, deviate from their lanes, and commit risky intersection maneuvers (Baldwin, 2002). Kostyniuk, et al. (1997), agrees that while older drivers do require more time to view navigational displays and suffer from impaired spatial and navigational ability, older drivers can overcome some of these impairments through the assistance of a good navigation system which can offset the common challenges experienced by older drivers.

Hypothesis

It was hypothesized that older users would require more time to process the map information, especially for the more complicated map concepts due to the increased number of stimuli to process. The response times associated with longer cognitive processing and

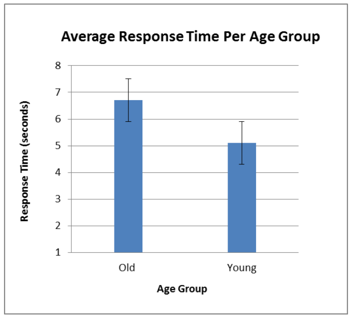

Figure 2: Older participants required significantly more time to respond compared to younger participants.

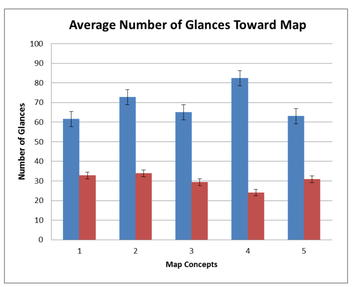

Figure 3: Older participants had significantly more glances toward the maps than younger participants.

easier visual search would be seen in complimentary eye glance durations when viewing the stimuli.

Methods

This study took place in the San Francisco Bay Area. 31 participants took part in this study, with a total of 18 males and 13 females. Among these participants, 13 were 20-35 years old and 18 were 50 years old and above. All were native English speakers and had self-reported experience with digital maps. Additionally all participants self-reported no visual impairments beyond those that were remedied with corrective lenses. Participants were all compensated for their time.

Sessions lasted about two hours. Participants were required to drive in a driving simulator, wear an eye tracker, and interpret maps by answering questions. A stationary driving simulator was used using the VIRES virtual test drive program. Within the simulator, a Sony Vaio Duo 11 tablet was mounted and used to show the maps. The tablet was in an approximate location to that of current in-vehicle infotainment systems. Additionally, a Dikablis 2.0 eye tracker was used to collect eye gaze behavior. The set up can be seen in Figure 1.

Prior to beginning the tasks, participants completed a warm-up to familiarize themselves with the driving task (drive 100 km/hour on a straight road) and the general map interpretation task. The map interpretation task required identification and interpretation of the: route, destination, relative position, traffic alerts (via icons), traffic density, and parking information. All conditions were randomized across trials and participants. To prevent participants from responding to a question before the experimenter was finished asking, the map images were shown only after the question had been asked. Responses were recorded and timed via a digital stopwatch by the experimenter. After the driving portion, participants filled out questionnaires about the maps.

Data Analysis and Results

Mixed design ANOVAs were conducted to analyze the relationship between the map concepts and age for response time, self-reported difficulty completing the task, and glance behavior (glance behavior refers to the number of glances toward the map, average glance durations, and percentage of glances toward the map). There was a significant main effect for response time across age, $F\,(1, 180) = 13.79$, $p < 0.01$, with older participants taking longer to respond ($M = 6.71$ seconds, $SD = 0.28$ seconds) than younger participants ($M = 5.12$ seconds, $SD = 0.33$ seconds). There were also significant differences found in the eye behavior analyses. Older participants took about double the number of glances toward the maps ($M = 68.90$, $SD = 10.62$) compared to younger participants ($M = 30.20$, $SD = 11.47$), resulting in a significant difference between the two age groups, $F\,(1, 24) = 6.14$, $p = 0.02$. With regards to average glance duration, there were no significant differences found toward the maps, however younger participants had significantly longer average glance durations toward the driving scene ($M = 1.21$ seconds, $SD = 0.11$ seconds) compared to older participants ($M = 0.87$ seconds, $SD = 0.10$ seconds), $F\,(1,24) = 4.97$, $p = 0.04$. No other eye gaze behavior comparisons had significant differences.

Discussion

It was hypothesized that the older participants would have longer response times compared to younger participants due to older participants requiring more time to cognitively process the information. The results of the mixed ANOVA supported this hypothesis as older participants took significantly longer to respond, on average, compared to younger participants for every map concept. It would have been expected to see longer glance durations towards the map in the older participant's data, however there were no significant differences between the age groups. However, there were significant differences in the number of glances towards the maps. Older participants took about double the number of glances towards the map compared to their younger counterparts. Since the number of glances were significantly different, and the average glance durations toward the map were not significantly different between the two age groups, then it cannot be argued that older participants took shorter but more frequent glances to perceive the information. It is hypothesized that the older participants glanced at the maps more often in an effort to retain the information in working memory and/or conduct the visual search. Older individuals have been known to have reduced working memory capacities and have decreased abilities to process multiple pieces of information at once. As the older participants were processing the map information and conducting the visual search, it is hypothesized that they would look at the map more often to retain the information in their working memory and continue processing the information. Thus, the significantly higher number of glances toward the map reflect the older population's need to look at the map in order to not only conduct the visual search, but also keep the information active in their working memory. It is this increased number of glances that likely caused the overall significantly longer response times. These results are important when considering eyes off the road time. Older participants took longer to accomplish the tasks and took significantly more glances towards the maps compared to younger participants. Considering that older adults are known to be more susceptible to driving errors and unintentional risky driving behavior, infotainment use has the potential to escalate this behavior by distracting older adults from the driving task. The findings found in this report should be considered when designing and testing future navigation maps. It is suggested that researchers looking at in-vehicle infotainment-caused distraction use older age as a demographic requirement for part of their participant sample and review the number of glances required to accomplish the tasks. In an effort to encourage safe use of digital maps in the vehicle, makers of digital maps should ensure all drivers, including older adults, can safely and efficiently use digital maps to accomplish the navigational aspect of the driving task.

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