



The effects of cognitively demanding dual-task driving condition on elderly people's driving performance; Real driving monitoring



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ABSTRACT

Background: Using in-vehicle audio technologies such as audio systems and voice messages is regarded as a common secondary task. Such tasks, known as the sources of non-visual distraction, affect the driving performance. Given the elderly drivers' cognitive limitations, driving can be even more challenging to drivers. The current study examined how listening to economic news, as a cognitively demanding secondary task, affects elderly subjects' driving performance and whether their comprehension accuracy is associated with these effects.

Methods: Participants of the study (N=22) drove in a real condition with and without listening to economic news. Measurements included driving performance (speed control, forward crash risk, and lateral lane position) and task performance (comprehension accuracy).

Results: The mean driving speed, duration of driving in unsafe zones and numbers of overtaking decreased significantly when drivers were engaged in the dual-task condition. Moreover, the cognitive secondary task led to a higher speed variability. Our results demonstrate that there was not a significant relationship between the lane changes and the activity of listening to economic news. However, a meaningful difference was observed between general comprehension and deep comprehension on the one hand and driving performance on the other. Another aspect of our study concerning the drivers' ages and their comprehension revealed a significant relationship between age above 75 and comprehension level. Drivers aging 75 and older showed a lower level of deep comprehension.

Conclusion: Our study demonstrates that elderly drivers compensated driving performance with safety margin adoption while they were cognitively engaged. In this condition, however, maintaining speed proved more demanding for drivers aging 75 and older.

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1. Introduction

Due to an increase in life expectancy, the population of elderly people is rising and therefore their mileage is also expected to enhance over the coming years. It has been observed that car accidents involving elderly drivers have significantly increased during the recent years (Dellinger et al., 2002; Hu et al., 2000; Langford and Koppel, 2006). As Lyman et al. (2002) predicted, elderly drivers over the age of 65 will increase their involvement in crash fatalities to at least 11% by the year 2030. Several studies have suggest

that driving performance is significantly affected by aging, which may be attributed to physical and cognitive impairments (Aksan et al., 2015; Nader and Rakie, 2006; Sivak et al., 1995). As reported by previous studies, there is a nonlinear relationship between age and crash involvement ratio. Based on the average annual distance driven by each age group, younger-novice and older drivers face with a high risk of crash involvement (Plan, 2009). Although there are several reports explaining the impact of aging on driving performance as mentioned earlier, some research indicates a significant decline in fatality rate among drivers aging over 60, which might have arisen from the different travel patterns adopted by the older drivers in comparison to other age groups (Cicchino, 2015). Older drivers are less likely to commute and more inclined to make short trips; they also drive less at night (Cicchino, 2015; Plan, 2009). In

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addition, some other compensation strategies used by drivers help them increase the driving safety (Young and Lenné, 2010).

Given the proportion of driver's annual mileage in relation to crash rate, it seems that older drivers appear riskier than other age groups on the road. Previous studies show that older drivers (+75) have the highest crash rate among all the age groups (Eby et al., 1998). In addition, cognitive impairments which are likely to appear in age over 65 decline the driving safety (Aksan et al., 2015). However, the patterns of accidents vary among different groups of older people. Classifications of older people who are experiencing their third stage in life vary in different studies (Hoffman et al., 2005; Lee et al., 2003; Strayer and Drew, 2004). In general, older people are classified into three groups according to their frailty, physical and cognitive impairments, and immobility. These groups include "young old", with the age from 65 to about 74 (sometimes the concept of young old describes the ages 65–79); "middle old", from about 75–84; and "old-old", above 84 (sometimes described in terms of the years above 80) (Macnicol, 2006). This classification can address more issues related to the influence of age growth on driving performance in elderly drivers.

Several simulator-based and real experiment studies show that getting involved in nonvisual secondary tasks affects driving performance by distracting the drivers' attention (Bellinger et al., 2009; Fagerström and Lisper, 1977; Green, 2001; Haigney et al., 2000; Reimer et al., 2011; Schreiner et al., 2004). In addition, naturalistic data from a study including 100 cars showed that 78% of the crashes and 65% of near crashes were due to some form of inattention, with a majority due to secondary task distraction (Dingus et al., 2006; Neale et al., 2005). In general, engaging in various types of auditory-vocal secondary tasks including listening to audio systems, talking to other passengers, or conversing on hands-held and hands-free cell phones are common activities during driving. These activities may affect the driver's performance (Bellinger et al., 2009; Dibben and Williamson, 2007; Salvucci et al., 2007; Ünal et al., 2013). However, it seems drivers are able to compensate their driving performance, for example, by reducing the driving speed to meet the enhanced demand of dual-task conditions (Young and Lenné, 2010). On the other hand, regarding cognitive impairments among people aging above 65 years, engagement in nondriving cognitive tasks seem to be more hazardous in this group compared with the other age groups (Stutts et al., 2005).

One common non-visual secondary task through driving is listening to various radio channels or to music (Dibben and Williamson, 2007). Drivers prefer listening to something to change their mood, feel more relaxed, or entertain themselves on both familiar and unfamiliar roads during trips (Wiesenthal et al., 2000). Drivers have also stated that they listen to different radio stations for approximately 72% of their driving duration (Dibben and Williamson, 2007). Some studies show listening to radio programs enhances alertness, reduces stress (Thoma et al., 2013; Thoma et al., 2012), and creates a more positive mood (van der Zwaag et al., 2012); however, other materials, like driver-preferred music, influences driving behaviors and increases miscalculations and inaccuracies among young-novice drivers while completing six trips in an instrumented learner' vehicle (Brodsky and Slor, 2013). Generally, it seems that engaging in auditory tasks like listening to radio/music, conversing on the cell phone, or talking to other passengers is a source of distraction and may affect the driving performance (Brodsky and Slor, 2013; Charlton, 2009; Fagerström and Lisper, 1977).

Ebnali and Naseri (2011) reported that elderly people in Iran are mostly interested in listening to economic news especially while they drive on familiar roads. Fifty three percent of the drivers who passed over one of the heavy traffic highways in Tehran stated that they often listened to social and economic news items cast 7:00–8:00 am (Ebnali and Naseri, 2011). It is suggested that lis-

tening to radio helps drivers to cope with traffic workload and distracts them from the boring time of heavy traffic (Thoma et al., 2012). Although listening to music is a habitual behavior that may not distract drivers, it can exert influence on drivers' driving performance by triggering divided attention, information processing, and the cognitively demanding task of listening to complex contents (Just et al., 2008). A recent study reported that when elderly people drive in a driving simulator with a secondary cognitive task which requires participants to add auditory serial pairs of randomized digits, the drivers need to continuously allocate their attentional resources to both the driving and the secondary task, which leads to a decline in driving safety (Cuenen et al., 2015). Just et al. (2008) suggest that listening to a dialogue and comprehending auditory sentences during the driving activity affect the driver's performance. In their study, participants steered the vehicle with a computer mouse or trackball held in their right hand under two conditions: one in which they focused their attention on the simulated driving task alone, and one in which they also judged whether the presented auditory sentences describing world knowledge were true or false. The results demonstrated that more brain areas including parietal lobe, occipital, and the motor areas are activated while precise listening is taking place besides driving compared to the situation in which the driver is only driving. The activation level in the parietal lobe cortex dealing with the main activity of driving also decreases (Just et al., 2008). Therefore, it seems that the sentence listening task degrades the driving performance. Although listening to radio programs such as economic news is common among drivers, no study has yet been conducted investigating the effect of listening to economic news as a secondary cognitively demanding task on the driving performance of the elderly.

Whereas most of the previous studies have investigated the effects of listening to music and other radio programs on driving performance, the present study focuses on the effects of active involvement in listening to economic news as a secondary task with more cognitive demands. Additionally, the study focuses on drivers over the age 65 in a real driving condition. Most of the previous experiments were conducted using driving simulators (Boyle and Lee, 2010; Brodsky and Slor, 2013; Cuenen et al., 2015; Just et al., 2008). Simulator-based studies provide the opportunity to present drivers with a variety of stimuli in a standardized, safe, and controlled environment (Freund et al., 2002; Lee et al., 2003); however, simulators are not best suited for driving behaviors measurement (Regan et al., 2013). In real driving situations and uncontrolled conditions of normal driving, the driver's performance would be more reliable and generalizable, compared to simulator-based driving conditions, and the collected data would be closer to driver's behaviors in naturalistic conditions. Therefore, the current study aims to determine the effects of listening to economic news on driving performance in real driving conditions. We also intend to evaluate the elderly drivers' capability for coping with complexity of dual-task demands while driving in presence of an auditory-vocal secondary task. Moreover, we also study the relationship between participants' comprehension accuracy and their demographic and performance variables.

2. Methods

2.1. Participants

Twenty-two male participants aging 65–83 ($M=72.6$ years, $SD=5.33$) participated in the experiments. One hundred and seventy three subjects were recruited after an announcement in Shahrekord University and welfare association websites. Initially, the subjects were screened over the telephone regarding their age,

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