PERCEIVED FATIGUE AMONG AGING DRIVERS: AN EXAMINATION OF THE IMPACT OF AGE AND DURATION OF DRIVING TIME ON A SIMULATOR

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Abstract

Aging population is a worldwide phenomenon and in the next forty years, it will increase importantly. Older drivers are more at risk of injuries and deaths than other groups of drivers (e.g., Brorsson, 1989 ; Cotrell & Wild, 1999 ; Gresset & Meyer, 1994 ; Stutts, Wilkins & Vaughn, 2004). Fatigue has been identified as a leading cause of accidents among that group of drivers (Clarke, Ward, Bartle, & Truman, 2010). The aims of this study is to verify if perceived fatigue among two groups of older drivers varies according to their age group and if perceived fatigue increases in a 45 minutes driving experience in a driving simulator. Method: Participants were 25 drivers 55 years and older, who were asked to drive on a monotonous road in a simulator for about 40 to 50 minutes. Monotonous roads are well-known to cause fatigue (Thiffault & Bergeron, 2003). Participants were asked to rate their fatigue four times: before starting to drive, after 15, 30 minutes of driving (excluding the 10 minutes for habituation) and once the driving ended, on a scale varying from 0 (not at all) to 10 (very much fatigued). For further analysis, participants were divided in younger aging drivers (55-65 years old; N=13) and older aging drivers (66-75 years old; N=12). Results show that both groups of drivers perceive themselves as getting more tired with driving time and that there were no significant differences between groups. We will discuss these results in light of the importance of future research in the domain and we will conclude with the limits of the study and suggestions for further research.

Keywords: aging drivers, perceived fatigue, monotonous drive, simulator.

1 INTRODUCTION

In many countries, the percentage of people 65 and older will more than double between 2010 and 2050 (Sivak and Schoettle, 2012) and will also account for about 20% of the population. As for those aged 60 and older, who were 841 million in 2013, their number will reach two billion in 2050 (United Nations, 2013). Such a demographic change will have an impact on various aspects of daily life, among them road safety. Indeed, studies have shown that aging affects driving safety. For example, it has been documented that drivers 75 and over, by kilometers covered, have a rate of accidents, injuries and deaths higher than average, similar to the one found among drivers aged 16 to 24 (e.g., Brorsson, 1989 ; Cotrell & Wild, 1999 ; Gresset & Meyer, 1994; Stutts, Wilkins & Vaughn, 2004).

Among the leading causes of car crash in older drivers, there is the fatigue experienced at the wheel. Indeed, that group of drivers is five times more likely to be responsible of road accidents associated with fatigue than being a victim of crash due to fatigue (Clarke, Ward, Bartle, & Truman, 2010). Fatigue while driving is a difficult concept to define for different reasons, chief among them the fact that it is often used as synonymous to drowsiness or sleepiness (May and Baldwin, 2009). Furthermore, symptoms of fatigue and sleepiness are similar: decreased attention, increased eye blinking, frequent yawning, etc. (Summala, Hakkanen, Mikkola & Sinkkonen, 1999). Another difficulty with the research conducted on fatigue while driving is due to the fact that there is not one objective widely accepted measurement of fatigue, such as found with alcohol or drugs that can be detected and measured in the organism. In addition, fatigue is often self-assessed and is not always valid, as it depends on the driver's motivation.

Among factors that can increase fatigue, there is the time spent on a task, such as driving for a long period of time, or doing exhausting physical exercises. In the present paper, we define fatigue as a transitional state between wakefulness and sleep and, if not interrupted, can lead to sleepiness (Thiffault & Bergeron, 2003). In the order hand, sleepiness is the difficulty to stay awake with a high probability of falling asleep. Fatigue can be caused by physical effort or monotonous activities, while sleep deprivation is the cause of sleepiness (Brown, 1994). Taking a rest is the way to reduce fatigue, whereas sleep is the way to reduce sleepiness (Philip, Sagaspe, Moore, Taillard, Charles, Guilleminault & Bioulac, 2005).

In the present paper, we are specifically interested by task-related fatigue (May & Baldwin, 2009). That type of fatigue, while driving, can occur either because of the demand of the task (e.g., length of the journey) or because of the driving environment. Further, task-related fatigue can also be characterised as either active or passive. For example, having to drive in high-density traffic could provoke active task-related fatigue, whereas having to drive on a monotonous road could produce passive task-related fatigue (May & Baldwin, 2009). Factors such as physical and mental workload, motivation, monotony, time since last sleep, medication, etc. have been associated with drivers' fatigue (Di Milia, Smolensky, Costa, Howarth, Ohayon & Philip, 2011;Thiffault & Bergeron, 2003).

Driving is a complex activity, requiring fast actions against risks and it necessitates abilities such as good motor skills and fast treatment of information, in order to drive safely. Three aspects of errors, related to fatigue while driving, have been proposed: frequency of errors, amplitude of errors, and/or variability of errors (Jackson, Hilditch, Holmes, Reed, Merat & Smith, 2011). The consequences that follow at the performance level are: increased reaction time, higher inattention/distraction, difficulty in stabilizing speed, a late correction in trajectory resulting in increased drifting within lane (Jackson, Hilditch, Holmes, Reed, Merat & Smith, 2011; Thiffault & Bergeron, 2003).

Because aging is associated with physiological impairment and functional declines at the cognitive skills level, it is possible that fatigue increases even more the impact of these impairments and declining abilities on the driving performance (Eby & Molnar, 2012; Oxley, Langford, Koppel, & Charlton, 2013). Furthermore, aging is often associated with the emergence of chronic diseases and medication intake, which may impair even more the driving skills of older drivers (McGwin, Sims, Pulley, & Roseman, 2000; Verster, Veldhuijzen, & Volkerts, 2004).

The study presented here has two objectives: A first one is to verify if there are age differences among aging drivers on perceived fatigue after driving in a monotonous environment. A second objective is to test if a driving session lasting 45 minutes in a simulator would permit to detect an increase in perceived fatigue over time. Comparisons of male and female participants, and age group belonging, on the following variables were also conducted: mean age, number of years driving, number of kilometers driven each week, number of hours slept on average each night and perceived fatigue.

2 METHOD

2.1 Participants

In this study, participants were 25 adults drivers, aged between 55 and 76 years old, with a mean age of 67,24 years old (*SD* = 6,20). There were 14 women and 11 men and 12 of the participants were in the 55-65 age group (M: 60,83 , *SD* = 2,59) and 13 in the 66-76 age group (M: 72,00 , *SD* = 3,42). All participants had a valid driver's license. Their declared medical condition during the screening telephone interview was satisfactory, 20 of them declared wearing glasses or contact lens. Seventy-two percent of these participants indicated that they took medication daily. Participants had been driving an average of 45,48 years (*SD* =

9,93), drove an average of 5,36 days a week (*SD* = 1,6), and an equal number of them indicated driving between either 20-50, 50-100 or 100-150 km per week.

The participants were recruited through a list of drivers provided by a Canadian Automobile Association and from an ad published in the e-journal of the university. The persons on the list of the automobile association were contacted by phone and informed the Foundation of their automobile association was associated with the conduct of a research on fatigue on driving and were asked if they would like to know more about the research. Following a hit, respondents were given some information about the study and were asked some questions in order to check if they met the study selection criteria (e.g., driving a minimum of two days a week, be a non-user of medication affecting the capacity to drive, not sick when reading in transports[1]). A similar interview was used with people responding to the ad.

2.2 Research Site, Stimuli and Apparatus

The results presented here come from a study that was the second step of a larger research project including five steps. This study took place in a laboratory of a large urban university which includes a fixed-base driving simulator, comprising a complete automobile, fully equipped with functional pedals and a dashboard (Fig.1). The driving simulation was projected on a large screen reproducing a drive on a monotonous country road, taking the form of an oval of around six kilometers. Monotonous roads are well-known to cause fatigue. The simulation drive was similar to another experimental drive, done a week earlier on-road in a closed-circuit course. The simulation environment is interactive and measures take participants' real-time behaviors. All driving sessions were audio-recorded and video-recorded.

Figure 1 - The driving simulator

2.3 Procedure

Participants were met outside the building and most of them had been driven to the university by a hired driver, or came by public transport. This procedure was followed in order to assure the participants would not have to drive right after driving on the simulator, in case of simulator sickness. Once in the laboratory, participants first completed a short questionnaire which was a follow-up of the questionnaire answered during the previous week in the on-road experiment. In addition to numerous questions, participants had been provided with an informed-consent form, which indicated that they would be audio- and video-recorded and that they could stop their participation at any time (with full compensation) during the experiment[2]. All participants received financial compensation (20 Canadian dollars) for the experiment.

Second, the experimenter explained the task on hand and how the experiment would progress on the fixed-base laboratory driving simulator. Participants first completed a practice trial (10 minutes), followed by the driving session that lasted an average of 45 minutes. Participants were asked to respect a 60 kilometers/hr limit. This limit was set in order to avoid as much as possible simulator sickness which increases with speeding. The simulation environment is interactive and measures take participants' real-time behaviors. All driving sessions were audio-recorded and video-recorded. Once the driving session completed, participants were administered a short questionnaire on simulator sickness (The *Simulator Sickness Questionnaire* from Kennedy, Lane, Berbaum & Lilienthal, 1993) and level of discomfort felt during the drive.

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[1] This is to eliminate as much as possible potential participants susceptible to simulator sickness.

[2] The research received the approbation of the ethic committee from the university of the responsible researcher.

2.4 Measures and Analysis

For the present study, the analysis and results focus on perceived fatigue during the 45 minutes experimental driving session and the comparison of the two age groups. The level of perceived fatigue was measured on a scale ranging from ''0'' *not at all fatigued* to ''10'' *very much fatigued* at four times during the experimental session. Each participant was asked his or her level of fatigue just before starting driving (Time1), after 15 minutes of driving once the experiment had started (Time2), after 30 minutes (Time3), and when the driving experiment ended (around 45 minutes) (Time4). Participants were divided in two groups: the 55-65 age group (group1) and the 66-76 age group (group2).

3 RESULTS

Twenty-five participants took part in that phase of the study (14 women and 11 men).

3.1 Male and Female Participants

Firstly, analyses were performed to verify if there were significant differences between female and male participants on the following variables: age, number of years number of years since the driving permit was obtained number of kilometers driven each week, number of hours slept the night before the experimentation and perceived fatigue. Results show no significant differences between men and women on all variables (all *t-test*=*n*.s.).

3.2 Age Groups

The second analyses were conducted in order to verify if the two age groups differed significantly on the same variables. The results of these analyses show that most of the results are not significant, except for the number of years since the permit was obtained, older drivers having their permits for longer (M: 49, *SD*: 9,18) than the younger group (M=39 *SD*: *SD*: 8,15), such as would be expected, $t(23) = -2.2$, $p < .05$. However, after a bonferroni correction, that result was no more significant.

There were no significant differences between age groups for perceived fatigue before driving, and after 15 and 30 minutes driving, but there was a significant difference at the end of driving session (45 minutes), t $(23) = 2.07$, $p < .05$, perceived fatigue being higher for the 55-65 age group than for the 66-76 age group (see Table 2).

3.3 Age Groups and Driving Time

The thirdly, a repeated analysis of variance (rANOVA) was conducted in order to determine if there was a significant effect of age group belonging (group1 and 2), and time driving on perceived fatigue (times 1, 2, 3, 4) and or a significant interaction age group X driving duration on perceived fatigue. Because of some missing data, one of the male participants had to be excluded from these analyses. The results of the rANOVA show that the age group had no significant effect on perceived fatigue while driving $F(1, 22) = 2.03$, $p > .05$. However, there was a significant effect of driving time on perceived fatigue $F(3, 22) = 9.59$, $p < .001$. Table 2 shows the means of perceived fatigue for both groups, just before starting the driving experiment (Time 1) through the end of the driving experiment (Time 4). The interaction was non significant ($F(3, 66) =$ 0, 19, $p > .05$).

Table 2. Mean and Standard Deviation of perceived fatigue for both groups

	Age Group 55-65		Age Group 66-76	
	Mean	SD	Mean	SD
Time 1 (N=24)	2.09	2.84	1.23	2.28
Time 2 (N=24)	3.91	2.39	2.69	2.14
Time 3 (N=24)	4.91	2.34	4.15	2.64
Time 4 (N=24)	5.36	3.08	3.77	3.37

The within-subject contrasts indicated significant differences between perceived fatigue for between Time 1-Time 2 and Time 2 -Time 3 ($p < .05$, $p < .001$ respectively), whereas the contrast Time 3 Time 4 was not ($p > .05$).

4 DISCUSSION AND CONCLUSION

Overall, the present results support the relevance of conducting a task-related fatigue with an aging population in a driving simulator. Indeed, the longer the drive, the more fatigued the participants perceived themselves, be they between 55-65 years of age or 66 to 76 years old. In the present study, perceived fatigue did not differ significantly between the two age-groups before or during driving. However, once the driving session was over, the older group declared to be less fatigued than the younger group, such as shown by the t-test. The fact that the age group difference in perceived fatigue once driving ended was not corroborated by a significant interaction age by time could be due to the lack of power associated with the small number of participants.

The results showing that older drivers were less fatigued at the end of the driving session could also be due to a confounding variable. In such a case, another variable not taken into account, either measured but non-significant because of the small number of subjects (N=25) or not measured, would explain better or more directly perceived fatigue than the number years since having the driving permit. For example, it is possible that experiencing less stress (there are more retirees in that group than in the younger group), would more directly explains a drop in perceived fatigue at the end of the experiment.

Another possible explanation relates to the time of day of the driving session. It is possible that more participants had their driving session in the simulator in the morning, rather than the afternoon, explaining why they perceived themselves as less fatigued at the beginning of the experiment. Indeed, some studies have shown that drivers 60 to 75 years old experience more fatigue between 3 to 6 o'clock in the afternoon (e.g., Gruau, Pottier, Davenne et Denise, 2003). Our participants drove on the simulator at one of 4-time periods: from 9:00 to 11:00 a.m.; from 11:00 a.m. to 1:00 p.m.; from 1:00 p.m. to 3:00 p.m.; from 3:00 p.m. to 5:00 p.m. Because of the small number of participants in each group, it was impossible to verify if participants from the 3:00 p.m. to 5:00 p.m. period perceived themselves as more fatigued than the participants who drove at other times of the day. Other studies, with larger samples of aging participants are necessary to clarify these results.

Another variable that may be associated with fatigue is the number of kilometers driven per year. In studies conducted by Langford and colleagues with large samples of drivers 75 years and older, they found that the age-related increase in Motor Vehicle Accident (MVA) was related to low mileage driven per year (3,000 km or less/year: Langford, Koppel, Charlton, Fildes, & Newstead, 2006; Langford, Methorst, & Hakamies-Blomqvist, 2007). It is possible that drivers limit their driving because they are more easily fatigued, and that it is why they have more MVA, rather than because they drive less kilometers per year. In the present study, we measured the number of kilometers driven per week, instead of per year. Our results show that it is not related to perceived fatigue.

Among the limits of this study, fatigue has been evaluated with a subjective measure. However, some studies have shown that subjective measures of fatigue can be a good predictor of real fatigue while driving. For example, in a study by Smith and colleagues (Smith, Carrington, & Trinder, 2005) it was found that subjective measures of fatigue were associated with predicted estimates of driving among young drivers. Results also showed that participants continued to drive in spite of perceiving themselves as sleepy. Future research should also verify if this would be the case with older and more experience drivers.

Other limitation of our findings is the fact that the study took place on a simulator in a laboratory. In order to increase the validity of the present results, studies are needed in order to compare perceived fatigue in a simulator with perceived fatigue on-road. It is possible that perceived fatigue is higher on-road, because numerous events or circumstances can interfere with the driver's concentration on his driving (cognitive overload) even if the driving environment is monotonous. Or the reverse could be true. It is also possible that the results achieved in the present study would be similar to a driving session on-road. In a study by Lee, Cameron and Lee (2003), results obtained with 129 older drivers who drove in a simulator and on-road gave support to the ecological validity of the driving simulator. However, they used a STISIM driving simulator which differs substantially from a normal car. In addition, their study dealt with numerous tasks associated with driving but not fatigue. Thus, it would be important to conduct a study verifying the ecological validity of a simulator resembling a real car and with a focus on a driving task inducing fatigue.

Finally, future research in that domain should also test the ecological validity of objective measures of fatigue, such as steering wheel movement (SWM) or difficulty in stabilizing speed. For example, in a study by Thiffault and Bergeron (2003), it was found that driving performance changed (more SWM) in more monotonous environments, implying fatigue. In that sense, a thorough exploration of the ecological validity of various performances measures implying fatigue would be very useful in better understanding its impact on driving, with different groups of drivers as well as aging drivers. However, such a comparison of various measures would necessitate a larger sample than the one the resent study could afford. Thus the need for such studies with larger samples.

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