The Effect of Age and Gender on Task Performance in the Automobile

L. Skrypchuk, A. Mouzakitis, P. M. Langdon and P. J. Clarkson

Abstract The automobile is becoming more complex as vehicle technologies advance. As a result, driver awareness of internal and external aspects of the environment will influence performance for a range of activities. Inclusivity is an important aspect of vehicle design, especially as autonomous driving functionality increases. This paper examines how users of differing gender and age perform within the vehicle. A simulator study was carried out to assess performance on a range of tasks, whilst driving under different driving conditions. The results show that differences exist between males and females, and older and younger operators for a range of driving and non-driving measures. Older operators generated higher steering wheel variation than younger drivers in driving-only conditions, whilst older and female operators require more button presses and glances away from the road than younger and male operators. The implications relating to in-vehicle interface design are discussed.

1 Introduction

There are many aspects of the automobile that are changing rapidly, such as alternative power sources (Zapata and Nieuwenhuis 2010) and autonomous driving (Luettel et al. 2012). These are aimed at reducing the impact of large global issues such as CO2 emissions and vehicle safety. As such, rapid changes are also being

L. Skrypchuk (✉) · A. Mouzakitis
Jaguar Land Rover Research, Coventry, UK
e-mail: LSKRYPCH@jaguarlandrover.com

A. Mouzakitis
e-mail: AMOUZAK1@jaguarlandrover.com

P. M. Langdon · P. J. Clarkson
Cambridge Engineering Design Centre, University of Cambridge, Cambridge, UK
e-mail: pml24@eng.cam.ac.uk

P. J. Clarkson
e-mail: pjc10@eng.cam.ac.uk

P. Langdon et al. (eds.), *Breaking Down Barriers*,
https://doi.org/10.1007/978-3-319-75028-6_2

made on the interior of the vehicle. The number of features and technologies offered to consumers is increasing (Abelein et al. 2012). Thus, whilst drivers are in manual control, another factor associated with vehicle safety is the impact these alternative tasks have when attempted in parallel with driving. Whether built-in onboard or through brought in devices (such as mobile phones), the user has access to more functionality than ever. Many of these cause the driver to shift attention away from the road. This combined with human desire to access information, increasingly fuelled by a fear of missing out, increases the likelihood of multitasking in the car (Przybylski et al. 2013).

Multitasking in the vehicle can be classified in a number of ways. The first relates to the driving act itself. The driver has to navigate, manoeuvre, check speed and avoid hazards, all of which have to be carried out successfully to complete a journey. The second type is when the driver attempts to carry out a Non-Driving Related Activity (NDRA) whilst the Driving Related Activity (DRA) is active, achieving this either in serial or parallel mode (Salvucci et al. 2009). It is this second type of multitasking that will be the focus of this paper.

One aspect of this challenge is the effect of natural variation within the user group and to what extent differences are evident that may impact how the vehicle systems are designed. Two prevalent differences are gender and age. Figure 1 shows the profile of active drivers in the United States of America. The first observation of note is the equal split of gender between male and female drivers, whilst the second is the wide age range. This diverse profile potentially makes designing and testing interface systems more challenging, especially when combined with the increasing complexity found within the driving environment. The question therefore being considered here is what is the effect of gender or age on performance in an automotive multitasking situation? This question will be examined using a driving simulator study along with a discussion about the implications for interface systems.

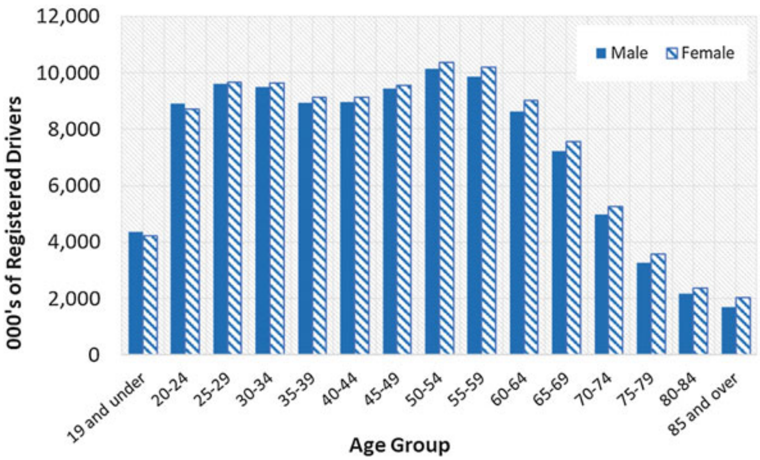

Fig. 1 Age profile of drivers in the United States of America, accurate as of 2015 (FHWA 2015)

1.1 Age and Gender Differences

Previous research has shown effects of both gender and age on human performance. Age appears more frequently in the literature. A number of the age-related findings are associated with reduced performance with old age, such as eyesight (Guirao et al. 1999), psychomotor response (Smith et al. 1999) and cognitive function (Hasher and Zacks 1988) amongst others (Charness and Bosman 1994, Reimers and Maylor 2005). Higher level functions, such as anticipation of hazards, gained through many years of experience, however, are sometimes lacking in the young (Borowsky et al. 2010).

There has been a large amount of age-related driving research focussing on different aspects of driving control through to the effects of multitasking. A number of simulator and real-world studies have been carried out to assess how age affects driving behaviour. Borowsky et al. (2010) found that older adults are more able to recognise hazards than younger adults when presented with videos of hazardous situations. Another study looked at age-related decline in cognitive ability and found differences in driving behaviour for older adults, such as adopting a larger headway to a leading vehicle. They also found that older drivers with high cognitive ability showed a greater ability to anticipate hazards, whilst the converse was true for younger drivers (Andrews and Westerman 2012). Crook et al. (1993) found a decline in performance relating to cognitive rather than psychomotor factors when testing reaction time in a simulator study. Kline et al. (1992) established that there are a number of factors caused by visual difficulties. Visual processing speed, light sensitivity, dynamic vision, near vision and visual search are areas where older drivers struggle. Related to this, Wood and Troutbeck (1994) found driving performance reductions for elderly drivers with cataracts when compared to elderly and younger drivers with normal vision. Cantin et al. (2009) found that driving led to a greater perceived mental workload for older drivers, an effect that heightened under complex driving environments.

A number of age-related studies have focussed on distraction. Shinar et al. (2005) looked at how younger and older adults dealt with phone conversations whilst driving. They found diminishing interference with practice across all age groups, especially in the young, as a result of learning. Older groups showed greater interference and a slower learning effect than younger adults. Horberry et al. (2006) found stable effects, regardless of age, with different environment complexities and in-vehicle tasks. This pointed towards no major differences as a function age. Hakamies-Blomqvist et al. (1999) used an instrumented vehicle to establish that older drivers were less able to multitask than younger driver. They found that younger drivers were able to use more concurrent controls than older drivers. This pointed towards a serial mode of operation for older drivers. Ponds et al. (1988) used a driving simulator and three age groups to examine performance under divided attention. The older group performed significantly worse than the middle-aged and younger groups who performed similar. Thompson et al. (2012) found that distraction caused reduced driving performance when comparing middle-aged and elderly drivers. The middle-aged drivers show the greatest variation.

When it comes to gender, there are clear physiological differences. The same is true for attitudes towards driving risk, including distraction, that may lead to performance differences. The result could be that males and females differ in how they handle the operational aspects of driving, such as acceleration, braking, car following distance, lane keeping and manoeuvring. If these basic driving behaviours differ, the same may be true for multitasking. In gender research to date, DeJoy (1992) found, when using a subjective questionnaire, that female drivers took driving incidents more seriously than males but both had similar perceptions of the frequency and likelihood of accidents. Similarly, Yagil (1998) found that males had a lower perception of the importance of traffic laws compared to female drivers. In an empirical study, Mäntylä (2013) found that in a multitasking situation, where one of the tasks was monitoring, that males outperformed females. This was explained by differences in spatial awareness. Rhodes and Pivik (2011) carried out a survey of teen and adult drivers to establish a relationship between risk perception, positive affect and risky driving. They found that risky driving behaviour was more likely to be found in teen males than in adult females. Simon and Corbett (1996) found that females offended on the road less often than males but experienced more stress as a result of an incident.

Despite a large amount of research on gender and age, there does not appear to be any distinction of the effect of performance on in-vehicle activities. In terms of gender-related driving research, there is a lack of reported empirical data regarding the relative performance of males and females and particularly for multitasking. Therefore, the key question relating to this paper is what effect does gender and/or age have on task performance in a multitasking driving situation. To answer this question empirically, an experimental study was carried out.

2 An Experimental Study

2.1 Study Design and Procedure

A low fidelity driving simulator was used to carry out the experiment at the research labs of Jaguar Land Rover, UK. Participants of varying age (groups of over and under 40 years of age) and gender were recruited against a specified profile. Sixty participants volunteered, were pre-screened for simulator sickness and asked to arrive for a specified time slot. The recruitment campaign resulted in a 56% male and 44% female split. The mean age of the over 40 group was 49.93 (±7 years) and 29.6 (±5.7 years) for the under 40 group. The experimental design was a repeated measures design with two factors, each with two levels: Age (under 40 years and over 40 years) and gender (male and female). The dependant variables collected were a range of performance measures relating to both the DRA and the NDRA. These were steering wheel position variation, speed, NDRA task time, button presses, mean number of glances per task and mean glance time. There were two main hypotheses. In Hypothesis 1 [H1], there will be a significant effect of age group on task performance measures and in Hypothesis 2 [H2], there will be a significant effect of gender on task performance measures.

The setup contained a half-vehicle cabin with integrated steering wheel and pedals (Logitech G27), a digital instrument cluster and centre console touchscreen. The roadway environment was represented in front of the driver on an 85 LCD TV containing a digital rear-view mirror. Side mirror displays presented wing mirror views. The driving environment was programmed using STISIM (v3) and consisted of a 10 min drive along a three-lane UK highway with typical lane width and curvature. Light to moderate traffic was programmed into the scenario whereby the driver had to periodically overtake slow moving traffic. During the drive, the participants were asked to maintain 70 mph and stay in the left-hand lane as frequently as possible. If they came upon a slower vehicle, they were asked to safely overtake the vehicle before moving back to the left-hand lane as soon as was safe to do so. This remained consistent between runs.

The in-vehicle tasks were all carried out using the centre console-mounted touchscreen, programmed using Qt (v5.7). Five tasks were used, all of which represented typical tasks available on a modern day automotive touchscreen. The tasks included were list scrolling, typing, option selection, menu navigation and setting adjustment. The simulator software reported several driving parameters (steering, lane position and speed) which were logged onto a PC. Moment-to-moment eye glance data was recorded from a SmartEye remote eye tracker (v6.1) mounted on the dashboard. Task performance data (button pushes, errors) was also recorded onto the same PC. All data was synchronised using a UNIX timestamp.

When participants arrived, they were asked to read an information sheet before signing a consent form. They were then asked to make themselves comfortable in the simulator by adjusting the seat and steering wheel. They were all given an opportunity to get used to the driving simulator setup during a brief familiarisation period which included them attempting to carry out the NDRA whilst driving. Following this, the participant was trained to some specific criteria on the NDRA interface to improve their awareness of how to successfully complete the tasks. The criteria consisted of observing the instructor complete the task before successfully completing the task five consecutive times themselves. Following this, they completed three further experimental runs. Each experimental run consisted of 1 min baseline driving periods interlaced with task epochs (counterbalanced in order). This and all subsequent runs lasted 10 min.

2.2 Results and Analysis

The data was coded and tested using a repeated measures ANOVA. The factors used were gender (male and female) and age group (Under 40 and over 40). No significant results were found for speed, NDRA task time or mean glance time ($p > 0.05$) and these are not included below.

2.2.1 Standard Wheel Position Variation

For baseline driving, the ANOVA of steering wheel position variation (Fig. 2; Table 1) found a significant effect of age group [$F(1, 152) = 8.18$, $p = 0.005$] with the over 40 s having a significantly higher steering variation than the younger group. There was no effect of gender and no interaction of gender by age group ($p > 0.05$). For multitasking, the ANOVA of steering wheel position variation (Fig. 2; Table 1) found no significant effect of gender, age group or gender by age group ($p > 0.05$).

2.2.2 Mean Number of Button Presses and Glances Per Task

For mean number of button presses (Fig. 3; Table 2), the ANOVA found a significant main effect of gender [$F(1, 143) = 6.14$, $p = 0.014$] and also for age group [$F(1, 143) = 12.72$, $p = 0.000$]. The female and over 40 groups requiring significantly more button presses to complete a task than the male and under 40 groups. There was no effect of gender by age group ($p > 0.05$). For mean number of glances per task (Fig. 3; Table 2), the ANOVA found a significant main effect of gender

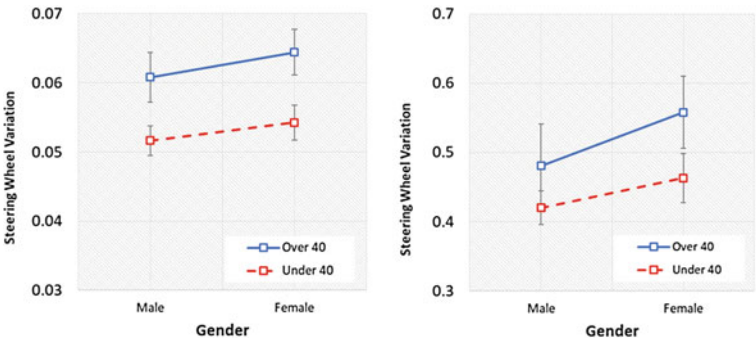

Fig. 2 Steering variation during baseline (left) and multitasking conditions (right)

Table 1 Steering variation for baseline and multitasking grouped by gender and age group, with the values in brackets indicating the standard error of the mean

Steering wheel position variation mean (standard error)		Baseline conditions		Multitasking conditions	
		Age group			
		Over 40	Under 40	Over 40	Under 40
Gender	Male	0.06078 (0.00359)	0.05165 (0.00213)	0.4804 (0.0609)	0.4199 (0.0245)
	Female	0.06439 (0.00329)	0.05424 (0.00254)	0.4199 (0.0245)	0.4629 (0.0355)

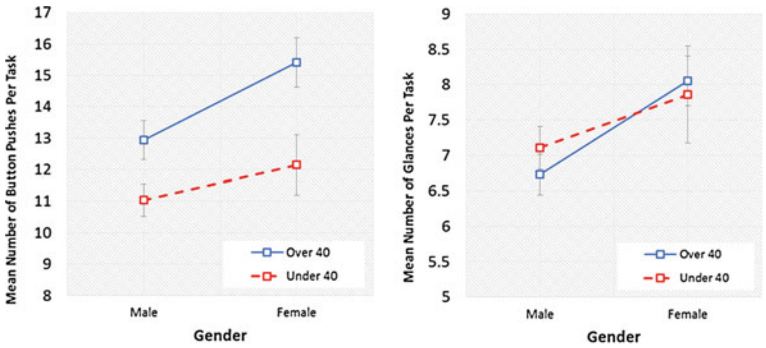

Fig. 3 Mean number of button pushes (left) and mean number of glance (right) per task

Table 2 Mean number of button pushes and mean number of glances per task grouped by gender and age group, values in brackets are the standard error of the mean

Mean (standard error)		Mean button pushes		Mean number of glances	
		Age group			
		Over 40	Under 40	Over 40	Under 40
Gender	Male	12.937 (0.613)	11.039 (0.519)	6.727 (0.285)	7.106 (0.303)
	Female	15.412 (0.795)	12.15 (0.958)	8.053 (0.353)	7.859 (0.688)

[$F(1, 151) = 6.86$, $p = 0.010$] with the female group needing significantly more glances per task than males. There was no effect of age group or gender by age group ($p > 0.05$).

3 Discussion and Design Implications

When looking at DRA performance, the baseline driving condition showed an effect of age group on general lane-keeping ability. The scenario used was consistent with typical highway driving, but even so, the effects of age group on steering wheel variation were evident in this simulator study. There was no effect of gender on baseline driving and so the male and female groups performed equally as well as each other. Figure 2 shows that the male participants mean steering variation value was marginally lower than the female participants mean steering variation. This was consistent between age groups with a high standard error seen with the over 40 s. This is as expected, the driving-only conditions were well within the capability of the operators. The scenario used was familiar and thus the only observation was that over 40 s were not as good at maintaining lane position as the under 40 s. This could be explained by any of the aspects described earlier (such as visual, cognitive or psychomotor).

This result in itself is not surprising but is important in the context of the multitasking data. First, the multitasking data were all significantly higher than the baseline data ($p < 0.05$). This was as expected, multitasking puts extra strain on the ability of the user to maintain lane position. The key difference was that the significant effect found in the baseline conditions within the age groups was not present in the multitasking data. The same trend as seen in the baseline data exists (over 40 and female groups producing a higher mean than the under 40 and male groups, respectively) but these differences were not significant. What is evident is that the variance (Fig. 2 standard error bars) is greater with respect to the mean values meaning a much greater variation in individual ability to maintain lane position. This is again not surprising considering that the NDRA takes focus away from driving and so deviations in lane are more likely. This makes corrective actions more likely and thus increases the amount of variation in wheel position.

For the NDRA performance, the number of button presses shows effects of both gender and age. For female participants, the over 40 s take two to three more button presses than under 40 s. The same distinction exists for the males where the difference is about one button press. Male participants took two to three fewer button presses than females to successfully carry out the same activities. This could be evidence of females making more errors or being less accurate with the touchscreen than the males. This points to consideration of button sizes and accuracy with this difference in mind. The differences in age are likely down to similar reasons, with under 40 s requiring fewer touches than over 40 s by around two to three pushes. Errors caused by physical or cognitive limitations are likely causes for the need to make more button pushes. There is also a potential exposure issue. Despite these participants being well trained in how to carry out these activities, younger members of society have more exposure to touchscreen devices and so could, in general, be more proficient.

For glance performance, effects were found for gender but not for age. The males required on average one fewer glances than females per task, indicating a difference in glance behaviour. Glance performance gives us indication of how drivers balance their visual resource between DRA and NDRA. More glances to a task could equally indicate more attention required to complete a task or a driver more conscious of the risk associated with the driving environment. The differences found here could be down to a number of reasons. One explanation could be linked to button presses. The greater number of button presses by female drivers could have led to the need for more glances. Another explanation could be the time required to find and locate a button. Longer visual search time leads to the need for more glances because of unsuccessful glance instances. This could also be explained by an increase in the number of glances back at the road for females influenced by risk aversion, as described in prior literature (DeJoy 1992).

In summary, there appears to be performance differences in baseline driving between age groups, but not between genders. There is also a general reduction in DRA performance between baseline and multitasking periods. What are the implications of these findings in terms of interface design? The first implication relates to the type of support on offer to the occupant. Interfaces that can help the user to maintain lane would certainly help to support the older individuals in this study. Equally, this functionality would offer support to all drivers during multitasking. The aim would be to reduce the amount of lane deviation during these multitasking situations and, therefore, could be activated when the user is identified as being multitasking.

This study demonstrates a general difference in steering performance between males and females. Although not significant, this could lead to making sure that there is a good balance of both in any testing campaign. This would help ensure that differences are accounted for in the evaluation process and assist in identifying issues that can be improved through an iterative design process. The gender difference may also offer insight into how interfaces could be more empathic. If females are more conscious of the effect of distraction, extra thought can be given to how an interface could be designed to be more conservative in this sense.

Consideration for the effects of age is required. Recent trends for minimalist graphics and modern design strategies that can make interpreting what a button is more difficult. This could increase the number of button presses (i.e. attempting to press something that is not a button) and glances (locating a button). In general, understanding the capability range of individuals with reduction in vision, psychomotor or cognitive performance, can help to develop better interfaces. Varying button sizes and greater clarity of touch areas could be applied dynamically, dependent upon age, to assist when multitasking (Biswas et al. 2014).

4 Conclusions

The act of multitasking in vehicle is very challenging. What is more, the design of interface systems that can take into account variation in the users attempting to use them is also complex. In this simulator study, there were significant differences found for a range of driving and non-driving tasks. For driving, there were no significant effects of gender but significant effects of age were found in relation to the variation in steering wheel movements. The over 40 age group produces a greater variation than the under 40 age group. Whereas for non-driving, significant effects for both age and gender were present with the male and under 40 age group producing fewer glances and button presses than the female and over 40 age group, respectively. This offers fresh insight into refining requirements for in-vehicle interface systems to account for differences that can influence performance for large numbers of people.

Acknowledgements This work is funded by Jaguar Land Rover Research through the Centre for Advanced Photonics and Electronics at Cambridge University.

References

Abelein U, Lochner H, Hahn D, Straube S (2012) Complexity, quality and robustness—the challenges of tomorrow's automotive electronics. Des Autom Test Eur Conf Exhib 870–871

Andrews EC, Westerman SJ (2012) Age differences in simulated driving performance: compensatory processes. Accid Anal Prev 45:660–668

Biswas P, Langdon P, Umadikar J, Kittusami S, Prashant S (2014) How interface adaptation for physical impairment can help able bodied users in situational impairment. In: Langdon PM, Lazar J, Heylighen A, Dong H (eds) Inclusive designing. Joining usability, accessibility and inclusion, pp 49–67, Springer

Borowsky A, Shinar D, Oron-Gilad T (2010) Age, skill, and hazard perception in driving. Accid Anal Prev 42:1240–1249

Cantin V, Lavallière M, Simoneau M, Teasdale N (2009) Mental workload when driving in a simulator: effects of age and driving complexity. Accid Anal Prev 41:763–771

Charness N, Bosman E (1994) Age-related changes in perceptual and psychomotor performance: implications for engineering design. Exp Aging Res 20:45–59

Crook TH, West RL, Larrabee GJ (1993) The driving-reaction time test: assessing age declines in dual-task performance. Develop Neuropsychol 9:31–39

DeJoy DM (1992) An examination of gender differences in traffic accident risk perception. Accid Anal Prev 24:237–246

FHWA (2015) Highway statistics 2015. US Department of Transportation, Federal Highway Administration. https://www.fhwa.dot.gov/policyinformation/statistics/2015/pdf/dl20.pdf. Accessed 5 Dec 2017

Guirao A, Gonzalez C, Redondo M, Geraghty E, Norrby S, Artal P (1999) Average optical performance of the human eye as a function of age in a normal population. Invest Ophthalmol Visual Sci 40(I):203–213

Hakamies-Blomqvist L, Mynttinen S, Backman M, Mikkonen V (1999) Age-related differences in driving: are older drivers more serial? Int J Behav Develop 23:575–589

Hasher L, Zacks RT (1988) Working memory, comprehension, and aging: a review and a new biew. Psychol Learn Motiv 22:193–225

Horberry T, Anderson J, Regan M, Brown J (2006) Driver distraction: the effects of concurrent in-vehicle tasks, road environment complexity and age on driving performance. Accid Anal Prev 38:185–191

Kline DW, Kline TJB, Fozard JL, Kosnik W, Schieber F, Sekuler R (1992) Vision, aging, and driving: the problems of older drivers. J Gerontol 47:27–34

Luettel T, Himmelsbach M, Wuensche H-J (2012) Autonomous ground vehicles—concepts and a path to the future. Proc IEEE 100:1831–1839

Mäntylä T (2013) Gender differences in multitasking reflect spatial ability. Psychol Sci 24:514–520

Ponds RWHM, Brouwer WH, Van Wolffelaar PC (1988) Age differences in divided attention in a simulated driving task. J Gerontol 43:151–156

Przybylski AK, Murayama K, Dehaan CR, Gladwell V (2013) Motivational, emotional, and behavioral correlates of fear of missing out. Comput Hum Behav 29:1841–1848

Reimers S, Maylor EA (2005) Task switching across the life span: Effects of age on general and specific switch costs. Dev Psychol 41:661–671

Rhodes N, Pivik K (2011) Age and gender differences in risky driving: the roles of positive affect and risk perception. Accid Anal Prev 43:923–931

Salvucci DD, Taatgen NA, Borst J (2009) Toward a unified theory of the multitasking continuum: From concurrent performance to task switching, interruption, and resumption. In: Proceedings of the 27th international conference on human factors in computing systems, CHI'09, Boston, MA, USA, 4–9 Apr 2009

Shinar D, Tractinsky N, Compton R (2005) Effects of practice, age, and task demands, on interference from a phone task while driving. Accid Anal Prev 37:315–326

Simon F, Corbett C (1996) Road traffic offending, stress, age, and accident history among male and female drivers. Ergonomics 39:757–780

Smith MW, Sharit J, Czaja SJ (1999) Aging, motor control, and the performance of computer mouse tasks. Hum Factors 41:389–396

Thompson KR, Johnson AM, Emerson JL, Dawson JD, Boer ER, Rizzo M (2012) Distracted driving in elderly and middle-aged drivers. Accid Anal Prev 45:711–717

Wood MJ, Troutbeck JR (1994) Effect of age and visual impairment on driving and vision performance. Transp Res Rec 84–90

Yagil D (1998) Gender and age-related differences in attitudes toward traffic laws and traffic violations. Transp Res Part F: Traffic Psychol Behav 1F(2):123–135

Zapata C, Nieuwenhuis P (2010) Exploring innovation in the automotive industry: New technologies for cleaner cars. J Clean Prod 18:14–20