Advances in Transportation, Vol. 60, 2022, 441–449
https://doi.org/10.54941/ahfe1002476

How Does Age Impact In-Vehicle Touchscreen Performance?

Lee Skrypchuk, Karl Proctor, and Dan Clifton

Jaguar Land Rover, Abbey Road, Whitley, Coventry, CV3 4LF, UK

ABSTRACT

Touchscreens are becoming commonplace in the modern-day vehicle, meaning they need to be accessible to all users, young or old. An experiment was conducted to understand the impact of age-related decline on touchscreen task performance when driving where users were asked to complete a simple touchscreen task in both a stationary (static) and moving (dynamic) condition. As expected, a significant decrease in task performance was found when comparing the static condition to a dynamic one. However, when analysing these two conditions by age, only the dynamic condition produced a significant decrease. A positive moderate correlation was also found in both conditions. This result has implications for the design of in-vehicle touchscreen systems to be inclusive of users of different ages and provides insight about the impact of when tasks are carried out in the vehicle.

Keywords: Human factors, Automotive user interfaces, Human performance, Age-related performance

INTRODUCTION

Touchscreens have become one of the main non-driving input devices in the modern-day automobile. As of 2020, it was estimated that 98% of new vehicles in the USA contained a digital display device, of which 97% had touch screen functionality (Barry, 2020). This shift has been driven by several factors, not least the ubiquity of touchscreens on consumer devices resulting in a rapid integration of touchscreen devices into In-Vehicle Information Systems (IVIS). The first IVIS touchscreens were seen in the late 1990’s but have only recently become dominant in an automotive setting. One of the advantages of touchscreen is the naturalness of interaction (Lin, 1993). By natural we mean that the system is operated by a simple pointing gesture using direct hand eye co-ordination. Touchscreens place the touch input element directly adjacent to the visual output, hereby eliminating the distance between input and output elements (Hutchins et al., 1985). Other advantages include workspace efficiencies, device packaging, durability, and adaptability (Shneiderman, 1991).

From a usability perspective, subconscious preference for in-car touch screens may exist. In a study looking at different input technology, many operators chose to use touchscreen for several tasks, when alternative input devices offering equivalent functionality were available (*i.e., rotary controller, touchpad and steering wheel controls*) (Large *et al.*, 2019).

However, possibly the biggest advantage is the ease of learning regardless of age. One example demonstrated that even young children can find touchscreens easy to learn when compared with other devices (Battenberg and Merbler, 1989). This expedient learnability can be useful in a vehicle to mitigate the difficulty associated with multitasking, and the impact of low frequency of use.

There are, however, several challenges relating to IVIS touchscreen use. One of these is a lack of physical feedback. There have been attempts at integrating haptic feedback, which can lead to improved performance (Pitts *et al.*, 2012), but comes at a financial cost to the vehicle manufacturer. There is also the impact of the driving environment. The motion created by the vehicle, influenced by the road surface and the nature of the pointing gesture, means that the success rate can be compromised due to increased perturbation (Ahmad *et al.*, 2015). Whilst this can be mitigated by design (Labio *et al.*, 2006), or technology advancement (Ahmad *et al.*, 2014), there will always be an influence due to vehicle motion because of the use of a pointing gesture. Other potential disadvantages include finger occlusion of the visual target, the potential for arm and neck fatigue for prolonged unsupported interactions, and reduced sensing reliability with gloves or other hand coverings (Hinckley, 2020).

The Impact of Age on Task Performance

Age is known to impact human performance in many ways. The key characteristics of aging can be broken down into four key areas (Caprani *et al.*, 2012); Perceptual (vision, hearing) (Young *et al.*, 2016; Ziefle and Bay, 2005), Psychomotor (impaired movement) (Chaparro *et al.*, 1999; Houx and Jolles, 1993), Cognitive (information processing and divided attention) (Craik, F. I. M. & Salthouse, 2008; Salthouse *et al.*, 1984), and Physical (strength and dexterity) (Adamo *et al.*, 2007; Skinner *et al.*, 1984). Each of these have the potential to negatively impact task performance in a vehicle, both with the touchscreen itself and also the driving task (Skrypchuk *et al.*, 2018). One of the main factors is cognitive impairment (Ponds *et al.*, 1988). Driving whilst interacting with a touchscreen is a task switching situation where mental workload can be high. It is known that under divided attention performance suffers due to age-related cognitive decline, therefore, both tasks are likely to suffer (Pak *et al.*, 2002). However, this is not always found to be the case (Somberg and Salthouse, 1982). Evidence suggests that there are some positives for older users when using touchscreen technology (Umemuro, 2004). In a study focused on understanding elderly users' resistance towards technology, the advantage of reconfigurability meant that many preferred touchscreens. Whilst this may not impact task performance, it will impact older users' acceptance of the technology. The potential impact of age on touchscreen performance is therefore evident, but by how much, and what relationship exists between age and performance? Vehicle manufacturers are obliged to develop systems that are inclusive (Clarkson and Coleman, 2015). Additionally, as the average age of the population increases more older drivers will be exposed to such systems. Understanding the relationship of performance

Table 1. Key research questions and associated hypothesis.

Research Question	Hypothesis
1. Does task performance differ between *Static* and *Dynamic* driving conditions?	A decrease in task performance in the *Dynamic* condition (H1)
2. Is there a difference because of age in these driving conditions?	A decrease in task performance for the *Older* age groups in both driving conditions (H2).
3. Is there correlation between task performance and age, for each condition?	A positive correlation in both the *Static* and *Dynamic* conditions (H3).

with a touchscreen and how it is impacted by age is as such an important characteristic associated with the design of IVIS.

Comparing the performance of older and younger users is commonplace in research (Findlater *et al.*, 2013; Motti *et al.*, 2013; Sonderegger *et al.*, 2016; Steinert *et al.*, 2015). However, it isn't always the case that performance declines (Roberts *et al.*, 2011), for example voice interactions have shown to produce very little detriment as a function of age. There have also been several experiments looking at the impact of age on driving performance (Dukic *et al.*, 2006; Pampel *et al.*, 2019; Ponds *et al.*, 1988; Skrypchuk *et al.*, 2018); (Ponds *et al.*, 1988) found that elderly participants were less efficient at dividing their attention. (Dukic *et al.*, 2006) found that driving performance and glance behaviour suffered for older drivers, this was concurred by (Skrypchuk *et al.*, 2018) who also found degradation in non-driving task performance. However, none of the prior research describes the magnitude of the change in task performance as a function of age in an automotive setting.

METHODOLOGY AND EXPERIMENTAL DESIGN

This paper describes an experiment carried out on a vehicle proving ground to understand the impact of age on touchscreen usability within a moving vehicle. Three questions were proposed and can be seen in Table 1. Before starting Ethical and GDPR guidelines were considered and allowed for the experimental setup to be refined accordingly. 34 participants were recruited to a specific age profile aligning to that of the premium vehicle market segment (*see Figure 1*). All participants consented for participation and were compensated for their time.

Experimental Design and Setup

Two independent variables were present in this experiment. The first was Driving Condition, and had two levels (*Static, Dynamic*). For the *Static* condition the test vehicle was stationary. For the *Dynamic* condition the vehicle was driven under controlled conditions on a test track. In both conditions the user was asked to carry out tasks on a touchscreen. The second independent variable was age, separated into two equal groups of participants (*Under 55, Over 55*). The test was carried out in a production specification vehicle, fitted with a 12.9" iPad (*Apple, USA*), mounted in the position of an automotive

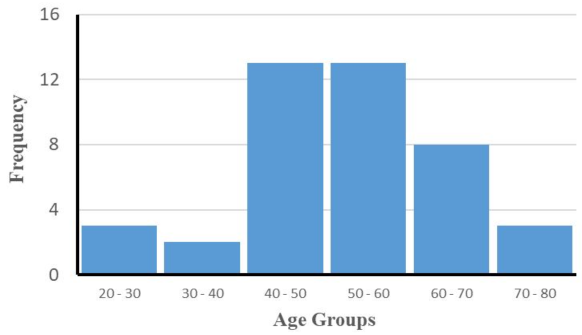

Figure 1: The age profile of participants in the experiment.

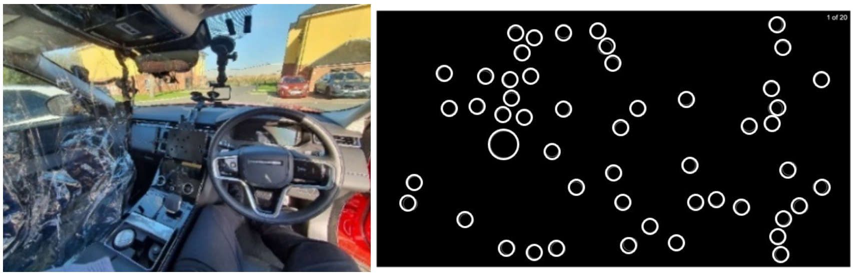

Figure 2: The experimental vehicle setup and surrogate reference task.

touchscreen device. Button press data was collected such that response times could be recorded.

The two tasks used in the experiment were (1) the driving task, and (2) a touchscreen task. For the driving task (*only active during the Dynamic condition*) participants were asked to maintain a speed of 50mph, whilst staying in their current lane. Tasks were conducted on a mile long straight section. For the touchscreen, an abstract reference task was used to avoid any bias associated with the task itself. The visual-motor Surrogate Reference Task (SuRT) (BSI, 2012; Wynn and Richardson, 2008), set at a moderate difficulty level, was selected to provide a consistent, error-free level of performance that could be easily learnt, and where the performance of the user would be entirely down to their physical and cognitive characteristics. The SuRT task (*as shown in Figure 2, right*) required the user to find and touch a target circle (*larger*) amongst other distractor circles (*smaller*). The task is user paced and requires visual load to locate the target, cognitive load to distinguish the target amongst distractors, and dexterity to operate. The hit area for each target was designed to be larger than the target to avoid any false pushes.

After the user had pressed the target, the screen reconfigured to a different pseudo random configuration. There were 20 targets in total and the task was balanced so that each quarter of the screen received an equal number of targets (5 in each quarter). The only dependent variable reported in this paper is the SuRT touch performance data, taken as the mean response time taken to select each of the 20 targets.

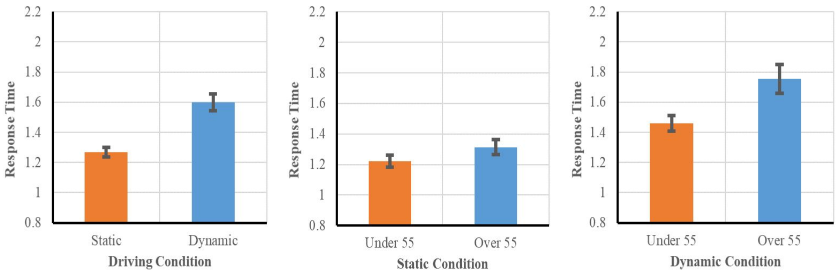

Figure 3: Response time (in seconds) for each driving condition, *under 55* and *over 55* age groups for both the *static* (centre) and *dynamic* driving conditions (right).

RESULTS AND ANALYSIS

All data was processed in excel and checked for the assumptions of each test used. The statistical analysis carried out using Minitab v19. The specific analysis used is reported in each sub section. There were three parts to the analysis of the SuRT performance data. Firstly, the two driving conditions were compared to see whether a performance difference existed (*Static* and *Dynamic*). Following this the sample was split into *Under 55* and *Over 55* groups for each driving condition to see if differences were present. Finally, all data was tested using a Pearson's correlation to see if any relationship existed between age and task performance.

Was a Difference Observed Between the Static and Dynamic Driving Conditions?

Figure 3 shows the mean response time for the two driving conditions. A two sample T-test was conducted to compare the response time performance. There was a significant increase in response time for the *Dynamic* conditions (M = 1.6, SD = 0.382) when compared with the *Static* conditions (M = 1.267, SD = 0.182; t (5.23), p<0.000).

Was a Difference Observed Between the Under 55 and Over 55 Groups?

Figure 3 shows the mean response time for the *Under 55* and *Over 55* groups by driving condition. A two sample T-test was conducted to compare the response time performance in both the *Under 55* and *Over 55* groups for the *Static* and *Dynamic* conditions. In the *Static* condition, there was no significant difference in response time for the *Over 55* group (M = 1.313, SD = 0.195) than for the *Under 55* group (M = 1.223, SD = 0.163; t (1.43), p = 0.164). For the *Dynamic* condition, there was a significant increase in response time for the *Over 55* group (M = 1.937, SD = 0.485) than for the *Under 55* group (M = 1.470, SD = 0.268; t (3.23), p = 0.006).

Was a Correlation Observed Between Task Performance and Age?

A Pearson correlation was computed to assess the relationship between response time and age. Figure 4 shows response time vs. age for both the *Static* and *Dynamic* conditions. For the *Static* condition, a moderate positive

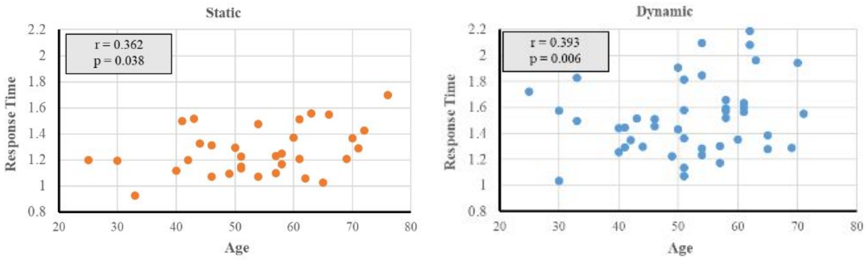

Figure 4: Plots of response time against age for the *static* and *dynamic* conditions.

correlation between the two variables was found (r(33) = .362, p = 0.038), while for the *Dynamic* condition, a moderate positive correlation was also observed (r(48) = .393, p = 0.006).

DISCUSSION AND CONCLUSION

The results show that, as expected, there was a decrease in performance due to test condition (*Static* vs *Dynamic*) confirming H1. This suggests that the characteristics of the *Dynamic* condition (*i.e., the concurrent tasks and the perturbation generated by the environment*) negatively impacted task performance. The ability of the user to perform the SuRT task sufficiently is impaired at a cost of the time taken to respond (*increase by approximately 0.333 seconds*). As each response was a single operation, this suggests that the time taken to look away from the road, locate the correct target, and operate the control is increased when driving by approximately 26%. This provides an understanding of the impact of carrying out a task while a vehicle is in motion, as opposed to when stationary, regardless of age. Unsurprisingly, the ability to focus entirely on the visual SuRT, and the lack of driving demand when stationary provides a better situation in which to complete visual manual tasks.

For the *Under 55* and *Over 55* groups, differences were found in the *Dynamic* condition, but not in the *Static* condition. This suggests that the operational conditions and the nature of the task, did not differ as a function of age when the vehicle was stationary (*Static*). However, the movement of the vehicle, and the added demand of the SuRT accentuated the impact of age, resulting in slower response time. Therefore, H2 can be confirmed for the *Dynamic* condition, but must be rejected for the *Static* condition. When we look closer, the differences between the conditions (*discussed earlier*) appear to have been heavily influenced by the *Over 55* age group where the difference between *Static* and *Dynamic* was 0.467 seconds, or 32% (*Static condition increased by 0.09 seconds or 7%*). This result suggests that even for a simple task, the differences caused by physiological and psychological decline can significantly impact how well users can carry out tasks on in-vehicle touchscreens whilst driving. This reinforces the benefits of completing a task when stationary for users of all ages.

Finally, a moderate positive correlation was found for both the *Static* and *Dynamic* conditions, suggesting that a relationship exists between response time and age. This can be used to quantify the impact of age on touchscreen performance in the vehicle. Both show a positive correlation of similar magnitude, suggesting that the increase is valid between the two test conditions used. This finding is particularly useful when looking at how a particular design might impact certain users. If a test can be carried out but can only be done with a limited sample or under laboratory conditions (*because of an inability to test dynamically due to lack of facilities, time, or a global pandemic*) a relationship can be drawn to understand the impact on specific users.

There were several limitations with this study. Firstly, the IVIS task used was a reference task, and not one traditionally seen in a real application, and therefore could have introduced a source of error. Relatedly, the SuRT targets used (*circles*) were consistent, known, familiar, and always visible. If the target was not salient, or on occasion missing (Gilchrist *et al.*, 2001) then the result may be different. Finally, the experimental setup and vehicle was new to the participants invited, and hence the novelty of the environment may have impacted the results.

To conclude, these findings have several implications for touchscreen IVIS design in future passenger vehicles. Firstly, the impact of performance can be expected to deteriorate the older the participant is, particularly when the vehicle is in motion, and hence this data can be used to characterize performance across the spectrum for different age ranges. This can be particularly useful if the recruitment for such studies limits participants ages to specific groups. Also, it opens questions about the right time at which to operate a touchscreen. Systems that promote use when the vehicle is stationary would clearly suffer less, as suggested by the findings in this paper. This highlights the impact of touchscreen use for users of a modern-day motor vehicle and the findings should be considered as part of the development process of future IVIS.

ACKNOWLEDGMENT

The authors would like to acknowledge the Jaguar Land Rover teams in the UK and in Portland, Oregon, USA, for their technical support. This work was part funded by a UKRI Future Leaders Fellowship [grant number MR/T021160/1].

REFERENCES

Adamo, D.E., Martin, B.J. and Brown, S.H. (2007), "Age-Related Differences in Upper Limb Proprioceptive Acuity", *Perceptual and Motor Skills*, Vol. 104 No. 3 II, pp. 1297–1309.

Ahmad, B.I., Langdon, P.M., Godsill, S.J., Hardy, R., Donkor, R. and Skrypchuk, L. (2015), "Touchscreen Usability and Input Performance in Vehicles under Different Road Conditions : An Evaluative Study".

Ahmad, B.I., Murphy, J.K., Langdon, P.M. and Godsill, S.J. (2014), "Intent Inference for Hand Pointing Gesture Based Interactions in Vehicles", *IEEE Transaction on Cybernetics*, Vol. XX No. Xx, pp. 1–12.

Barry, K. (2020), "Why Are Automakers Replacing Buttons With Touchscreens?", *Consumer Reports*, available at: https://www.consumerreports.org/infotainment-systems/screen-stars-in-car-infotainment-systems/.

Battenberg, J.K. and Merbler, J.B. (1989), "Touch Screen versus Keyboard: A Comparison of Task Performance of Young Children", *Journal of Special Education Technology*, Vol. 10 No. 1, available at: https://doi.org/10.1177/016264348901000103.

BSI. (2012), "PD ISO / TS 14198 : 2012 BSI Standards Publication Road vehicles — Ergonomic aspects of transport information and control systems — Calibration tasks for methods which assess driver demand due to the use of in-vehicle systems".

Caprani, N., E., N. and Gurri, C. (2012), "Touch Screens for the Older User", *Assistive Technologies*, No. 1, available at: https://doi.org/10.5772/38302.

Chaparro, A., Bohan, M., Fernandez, J., Choi, S.D. and Kattel, B. (1999), "The impact of age on computer input device use":, *International Journal of Industrial Ergonomics*, Vol. 24 No. 5, pp. 503–513.

Clarkson, P.J. and Coleman, R. (2015), "History of inclusive design in the UK", *Applied Ergonomics*, Vol. 46 No. PB, available at: https://doi.org/10.1016/j.apergo.2013.03.002.

Craik, F. I. M. & Salthouse, T.A. (Eds. . (2008), "The handbook of aging and cognition (3rd edition)", *Psychology Press*, Vol. 23 No. 03, available at: https://doi.org/10.1002/acp.1505.

Dukic, T., Hanson, L. and Falkmer, T. (2006), "Effect of drivers' age and push button locations on visual time off road, steering wheel deviation and safety perception", *Ergonomics*, Vol. 49 No. 1, pp. 78–92.

Findlater, L., Froehlich, J.E., Fattal, K., Wobbrock, J.O. and Dastyar, T. (2013), "Age-related differences in performance with touchscreens compared to traditional mouse input", *Conference on Human Factors in Computing Systems - Proceedings*, pp. 343–346.

Gilchrist, I.D., North, A. and Hood, B. (2001), "Is Visual Search Really like Foraging?", *Perception*, Vol. 30 No. 12, pp. 1459–1464.

Hinckley, K. (2020), "Input Technologies and Techniques Ken Hinckley", *The Human-Computer Interaction Handbook*, CRC Press, pp. 183–200.

Houx, P.J. and Jolles, J. (1993), "Age-related decline of psychomotor speed: effects of age, brain health, sex, and education.", *Perceptual and Motor Skills*, Vol. 76 No. 1, available at: https://doi.org/10.2466/pms.1993.76.1.195.

Labio, R.S., Rowan, C.P. and Shattuck, L.G. (2006), "Command and control on the move: Assessing the impact of input device, button size, and road condition", *Proceedings of the Human Factors and Ergonomics Society*, pp. 694–698.

Large, D.R., Burnett, G., Crundall, E., Lawson, G., Skrypchuk, L. and Mouzakitis, A. (2019), "Evaluating secondary input devices to support an automotive touchscreen HMI: A cross-cultural simulator study conducted in the UK and China", *Applied Ergonomics*, Vol. 78, available at: https://doi.org/10.1016/j.apergo.2019.03.005.

Lin, C. (1993), "User preference and performance with three different input devices: keyboard, mouse and touch screen.", *Educational Technology1*, Vol. 33 No. 7, pp. 56–59.

Motti, L.G., Vigouroux, N. and Gorce, P. (2013), "Interaction techniques for older adults using touchscreen devices: A literature review", *IHM 2013 - Actes de La 25ieme Conference Francophone Sur l'Interaction Homme-Machine*, pp. 125–134.

Pak, R., McLaughlin, A.C., Lin, C.-C., Rogers, W.A. and Fisk, A.D. (2002), "An Age-Related Comparison of a Touchscreen and a Novel Input Device", *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, Vol. 46 No. 2, pp. 189–192.

Pampel, S.M., Lamb, K., Burnett, G., Skrypchuk, L., Hare, C. and Mouzakitis, A. (2019), "An investigation of the effects of driver age when using novel navigation systems in a head-up display", *Presence: Teleoperators and Virtual Environments*, Vol. 27 No. 1, available at: https://doi.org/10.1162/PRES_a_00317.

Pitts, M.J., Burnett, G.E., Skrypchuk, L., Wellings, T., Attridge, A. and Williams, M.A. (2012), "Visual–haptic feedback interaction in automotive touchscreens", *Displays*, Elsevier BV, Vol. 33 No. 1, pp. 7–16.

Ponds, R.W.H.M., Brouwer, W.H. and Van Wolffelaar, P.C. (1988), "Age Differences in Divided Attention in a Simulated Driving Task", *Journal of Gerontology*, Vol. 43 No. 6, pp. P151–P156.

Roberts, S.C., Mehler, B., Orszulak, J., Reimer, B., Coughlin, J.F. and Glass, J. (2011), "An Evaluation of Age , Gender , and Technology Experience in User Performance and Impressions of a Multimodal Human-Machine Interface".

Salthouse, T.A., Rogan, J.D. and Prill, K.A. (1984), "Division of attention: Age differences on a visually presented memory task", *Memory & Cognition*, Vol. 12 No. 6, pp. 613–620.

Shneiderman, B. (1991), "Touch screens now offer compelling uses", *IEEE Software*, Vol. 8 No. 2, pp. 93–94.

Skinner, H.B., Barrack, R.L. and Cook, S.D. (1984), "Age related decline in proprioception", *Clinical Orthopaedics and Related Research*, Vol. 184, available at: https://doi.org/10.1097/00003086-198404000-00035.

Skrypchuk, L., Mouzakitis, A., Langdon, P.M. and Clarkson, P.J. (2018), "The effect of age and gender on task performance in the automobile", *Breaking Down Barriers*, Springer International Publishing, Cham, pp. 17–27.

Somberg, B.L. and Salthouse, T.A. (1982), "Divided attention abilities in young and old adults", *Journal of Experimental Psychology: Human Perception and Performance*, Vol. 8 No. 5, pp. 651–663.

Sonderegger, A., Schmutz, S. and Sauer, J. (2016), "The influence of age in usability testing", *Applied Ergonomics*, Vol. 52, pp. 291–300.

Steinert, A., Haesner, M., O'Sullivan, J.L. and Steinhagen-Thiessen, E. (2015), "Difference in operation of Mouse and Touchscreen in older adults", *International Journal of Serious Games*, Vol. 2 No. 4, available at: https://doi.org/10.17083/ijsg.v2i4.70.

Umemuro, H. (2004), "Lowering elderly Japanese users? resistance towards computers by using touchscreen technology", *Universal Access in the Information Society*, Vol. 3 No. 3–4, pp. 276–288.

Wynn, T. and Richardson, J.H. (2008), "Comparison of subjective workload ratings and performance measures of a reference IVIS task", *European Conference on Human Centred Design for Intelligent Transport Systems*, pp. 79–88.

Young, K.L., Koppel, S. and Charlton, J.L. (2016), "Toward best practice in Human Machine Interface design for older drivers: A review of current design guidelines", *Accident Analysis & Prevention*, Elsevier Ltd, Vol. 106, pp. 460–467.

Ziefle, M. and Bay, S. (2005), "How older adults meet complexity: Aging effects on the usability of different mobile phones", *Behaviour and Information Technology*, Vol. 24 No. 5, available at: https://doi.org/10.1080/0144929042000320009.