What drives off-road glance durations during multitasking – capacity, practice or strategy?

Robert Broström [1], Mikael Ljung Aust[1], Linnea Wahlberg[2], Laban Källgren[2]

[1]Volvo Car Corporation, Sweden

[2] Swedish National Road and Transport Research Institute (VTI), Sweden

Abstract

NHTSA has proposed compliance criteria for in-vehicle tasks in driving simulators. These criteria exclude usage of interfaces with too many long glancing participants. In the current study 30 participants performed three infotainment tasks while driving a high-fidelity driving simulator. Off-road glance durations for three data-trails were analysed to assess the prevalence of long glancers and possible reasons for the existence of long glancers. Results show that 85th percentile off-road glance durations were common, and significantly varied between participants. Also, the number of long glancers was reduced with repetition, but did not change between task types. Furthermore, there was no correlation between drivers' performance on a Trail Making Test and the 85th percentile off-road glance durations. Hence, variations in glance duration seem more to reflect individual glance strategies than in-vehicle task complexity or individual performance capacity measured by the Trail Making Test. The findings in this study have implications for further development of compliance testing procedures.

Introduction

Naturalistic driving studies indicate that looking away from the forward roadway for more than a certain period of time is a key crash contributing factor (Dingus et al. 2006, Klauer et al. 2006, Victor and Dozza, 2011, Liang et al. 2012). This fact, combined with the societal transition towards ubiquitous use of information technology, has put driver distraction on top of the traffic safety agenda. From a vehicle design point of view, many sources of distraction such as eating, drinking and interacting with passengers lie outside the manufacturer's influence. However, as OEMs do control the design of in-vehicle systems that involve visual-manual interaction while driving, guidelines that give recommendations on how to maximize usability and minimize distraction during visual-manual interactions are being incorporated in the vehicle design process (Broström, Bengtsson and Axelsson, 2011).

Several design guidelines have been published, including the European Statement of Principles (EU 2008), the JAMA guidelines (JAMA 2004) and the Alliance guidelines (Alliance of Automobile Manufacturers 2006). The latest addition is the visual-manual interaction in-vehicle system interaction guidelines proposed by the National Highway Traffic Safety Administration (NHTSA, 2012). This guideline approaches visual distraction in a two-step procedure. First, it lists certain tasks that always should be unavailable when driving, e.g., internet and social media browsing. For other tasks, the guidelines specify several criteria against which in-vehicle system tasks should be evaluated before being enabled during driving.

The publication of these guidelines is very timely and will drive vehicle safety forward. However, some formulations may need revision as new information comes to light, and the first off-road glance duration criterion that NHTSA proposes may be one of those. It reads as follows:

- For at least 21 of the 24 test participants, no more than 15 percent (rounded up) of the total number of eye glances away from the forward road scene should have durations of greater than 2.0 s while performing the in-vehicle task

To explain why this criterion may need revision, a short discussion on visual attention sharing between the forward roadway and an in-vehicle task is necessary. Such attention sharing can be portrayed as an iterative cycle. Drivers first look at the road to check their safety margins, then at the in-vehicle display to complete the next step in the current task, then back at the road again to check the safety margins, and so forth.

Drivers will generally try to get information from the in-vehicle task within a second or less, and then return their gaze to the road (Wierwille, 1993). If retrieval of adequate information takes longer they may continue to look away from the forward roadway some additional time. However, if it takes more than about 1.5 s (Wierwille, 1993), drivers return their gaze to the road and try again later, see Figure 1.

Human performance is normally associated with certain variability within and between individuals. Thus, even if all drivers have a point where they feel compelled to return their gaze to the road (Wierwille, 1993), it is unlikely that this point lies at the same value for all drivers. Some may prefer a faster cycle pace (i.e. a short glance on the display, a short glance on the road, a short glance on display, etc.), while others may be considered "long glancers", i.e. they dwell longer in each cycle step (Ljung et al., 2013).

The potential problem implied by such variability in relation to NHTSA's criterion is that as currently written, the criterion brings the pass/fail measurement of off-road eye glance durations down to an individual level instead of measuring at the group level. First, each individual is assessed based on whether they meet what can be called an 85^{th} percentile off-road glance duration criteria, i.e. whether at least 85 % of their off-road glances during a task are shorter than 2.0 seconds. Next, the proportion of drivers meeting this requirement is determined.

If we assume the off-road glance duration variability between drivers exists, some drivers may naturally prefer cycle times that will make them fail on the 85^{th} percentile criterion. Hence, if the relative prevalence of such natural "long glancers" is greater than the 3 in 24 allowed by NHTSAs criterion, then repeated random sampling of 24 compliance-test-participants will from time to time lead to failing in-vehicle tasks due to normal driver variability rather than poor task design. It is therefore important to find out if "long glancers" exist and how common they are in the normal driver population.

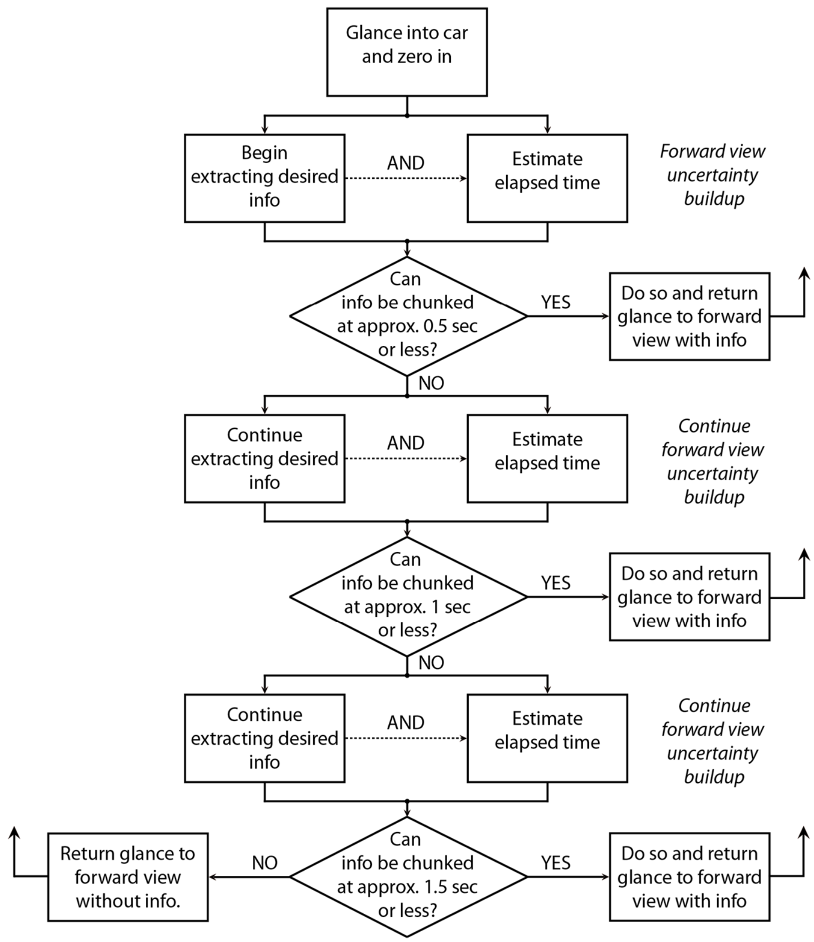

Figure 1 Model of visual sampling for in-vehicle task performance, Wierwille (1993).

There are good reasons to expect that this variability exists. One on-road study found that older drivers have longer total eyes-off-road times when completing in-vehicle tasks, and that they often glanced at the task display for more than 2 seconds at a time (Wikman and Summala, 2005). Another on-road study (Ljung et al., 2013) found that one out of six drivers had 85th percentile off-road glance durations longer than 2 seconds. Moreover, a simulator study found that drivers could be divided into three visual strategy clusters where the “high risk cluster” looked away from the road for the longest periods, and also had the shortest time to collision (Donmez, Boyle and Lee, 2010).

Still, more research on why these variations exist and how they can be controlled in compliance testing are needed. One possible reason could be that 85th percentile variability correlate with individual capacity in terms of visual search, motor speed and mental flexibility measured by the Trail Making Test (Crowe 1998). Such correlations have been found in on road studies that examined ageing and time-sharing (Wikman and Summala, 2005), ability among older drivers (Emerson, et al. 2012) and for individuals after brain injury (Hargrave, Nupp & Erickson, 2012).

Another possibility could be that the variability contain study artefacts, due to limited pre-test practice. For example, when test participants familiarize themselves with different tasks, large variability depending on e.g. previous knowledge could be expected. Thus, when measurements typically are made after a few trials, this artefact could capture that early variability.

A third possibility could be that this variability depends on differences in driver strategy, e.g. in risk taking (Donmez, Boyle and Lee, 2010), mismatch between invested effort and real world complexity (Broström and Davidsson, 2012), or due to variations in forward view uncertainty buildup (Wierwille, 1993) . However, regardless of which answer(s) turns out to be correct, between driver off-road glance duration variability needs further study.

The current study had two goals. One was to study the prevalence of “long glancers” among randomly recruited test participants. The other was to investigate possible reasons for the existence of long glancers in correlation with capacity, practice and strategy.

Methodology

The study was performed at the Swedish National Road and Transport Research Institute, VTI, driving simulator in Linköping, Sweden. The design was within-group. There were 30 test participants, though 14 had to be excluded due to poor eye-tracking quality. The remaining participants were 25 to 54 years old (M = 36, SD = 8.6), nine men and seven women. All had held their driving license for at least 5 years.

All participants performed a radio task, a phone task and a sound settings task while driving. The three tasks constituted a task set, and each set was repeated three times (see Table 1).

Table 1: Task type order in the study

Order	Task type	Repetition
1	radio	1
2	phone	2
3	sound settings	3
4	radio	1
5	phone	2
6	sound settings	3
7	radio	1
8	phone	2
9	sound settings	3

Apparatus

The vehicle mock-up is a Saab 9-3 Sport sedan MY 2003 with automatic transmission. The visual system consists of 3 DLP projectors (1280x1024 resolution) providing a 120 degrees forward field of view. A dedicated graphics card provides edge blending and geometrical correction. There are 3 LCD displays incorporated into the rear view mirrors for rearward views. Sound from vehicles, road and wind is simulated and presented via the in-vehicle speaker system. The moving base has three parts: a linear sled, a tilt motion system and a vibration table. The sled can provide linear motion with amplitude of ± 3.75 m at speeds up to ± 4.0 m/s and accelerations up to ± 0.8 g. The tilt motion system can produce pitch angles between - 9 degrees and + 14 degrees and roll angles of ± 24 degrees. The vibration table gives ± 6.0 cm in vertical and longitudinal movement, with a maximum roll angle of ±6 degrees and pitch angle of ± 3 degrees.

A tablet computer with a 9.7-inch touch screen was positioned in front of the centre stack in the car. The computer contained mock-up infotainment applications including phone dialling, radio tuning and sound settings. For eye-tracking, a four-camera system from Smart Eye Pro 5.9 (Smart Eye, n.d.) was used. Three cameras were positioned on top of the dashboard and one was positioned just to the right of the tablet computer. Data logging from the eye tracker was done at a sampling rate of 40 Hz.

After the simulator drive, the participants carried out a trail-making test. The test was performed on a 23-inch touch screen, where participants pressed target circle shapes with a width of 2.74 cm.

Driving task and in-vehicle tasks

The primary task was to drive on a motorway for approximately 30 minutes. The participants were instructed to drive as they normally would under similar circumstances and keep the speed limit (90 km/h). There was oncoming traffic at an average rate of three vehicles per minute and other cars overtook the participants on once a minute on average. They also caught up with slower vehicles which they had to overtake on average once every two minutes.

During the drive participants also executed three in-vehicle tasks on the tablet computer. The first task was to dial their own phone number. By pressing buttons on the display, participants first opened the phone feature and then the keypad, on which they dialled their phone number and pressed a call button. They then hung up by pressing another button. The participants were informed that the system was a mock-up and that no signal was sent to the receiving number.

The second task was to manually tune to a specified radio frequency. By pressing buttons on the display, the participants first opened the radio feature and then chose manual tuning. They tuned the frequency either by pressing a marker on a frequency band and then swiping it to the specified frequency or by pressing arrow buttons on each side of the frequency band.

The third task was to change the bass and treble levels in the sound settings. The sound settings display was opened by pressing buttons on the display. Bass and treble levels where then swiped into position.

Each task was initiated by a pre-recorded voice message instructing the driver task what to do and the details of the tasks, i.e. which radio frequency to tune in. After each in-vehicle task the participants were instructed to press a home button, so each task started from the same interaction point on the tablet computer.

The Trail Making Test

The Trail Making Test measures processing speed, sequencing, mental flexibility and visual-motor skills (Bowie and Harvey 2006). Traditionally it has two parts. In part A, participant connects a series of encircled numbers in numerical order by drawing a line between them. In part B, participants connects both encircled numbers and letters in order, alternating between numbers and letters (1-A-2-B-3-C and so on) (Bowie and Harvey 2006). In this study, a computerized version of the Trail Making Test was used (Summala, Etholén, Leino, Niskakangas, Laine & Saarinen, 2008). It was carried out on a touch screen where participants pressed the target circles, see figure 2.

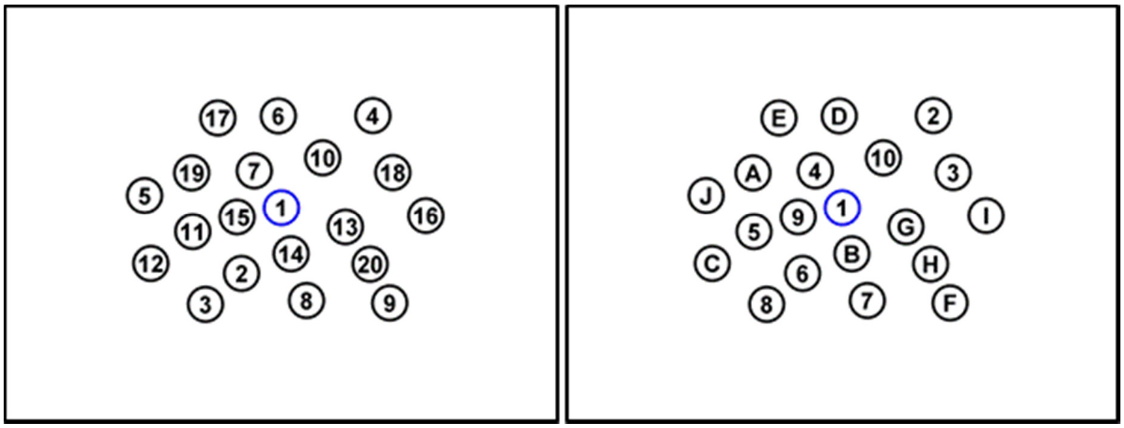

Figure 2

The screens for the trail-making test part A (left) and part B (right). All targets had black circles and the first target (1) was highlighted with a blue circle.

The test included part A and part B, where part A contained targets with fixed positions and part B targets which randomly changed positions after every press. Each round consisted of 20 targets and was carried out two times according to the order in Table 2.

Table 2: Task order in trail-making test

Order	Round	Targets	Positions
1	Part A fixed	Numerical	fixed
2	Part A random	Numerical	random
3	Part B fixed	numerical and alphabetical	fixed
4	Part B random	numerical and alphabetical	random
5	Part B random	numerical and alphabetical	random
6	Part B fixed	numerical and alphabetical	fixed
7	Part A random	Numerical	random
8	Part A fixed	Numerical	fixed

Procedure

On arrival, participants were given written and verbal information about the study and asked to sign an informed consent form. They were then given written instructions for the in-vehicle system tasks, and were instructed to try them out. They performed each task until they were comfortable performing them in parking mode. Next a 10-minute training drive followed, after which the actual test drive commenced. After the drive, participants read trail-making test instructions and made four practice rounds with 12 circles per condition. Next they performed the real test of eight rounds with 20 circles. The mean time between pressing two successive, correct targets was calculated for each of the four rounds.

Glance data reduction

In this study, off-road glance durations were defined as starting when the driver's gaze leaves the forward roadway and ending when gaze returns there. This does not follow the ISO 15007-1 standard (ISO), since it incorporates both the saccade to and away from the display, whereas the ISO-standard only includes the first.

Each task was defined as starting when a voice message announcing it was played and ending either when a new task started or 60 seconds after start of the task, whichever came first. Task length therefore varied between 23 and 60 seconds.

The eye-tracker data quality varied quite much between participants. To handle this issue, first, participants with a data loss exceeding 20 per cent were excluded from the study. The remaining 16 participants had data loss between 3.0 and 19.1 per cent (M = 12.8, SD =5.3).

In the current set-up, gaze direction is automatically calculated in reference to a set of 2D planes (i.e. dashboard, windshield, etc.) in a 3D model of the car compartment. Thus, the next step was to merge all off-road planes into one big off-road area. Next the raw data was smoothed using the text string equivalent of an 11-frame moving average filter, and off-road glance durations during task performance were calculated.

According to Rayner (Rayner 1998), fixation times when reading (which form a substantial part of in-vehicle system interactions) average around 225 ms. In Land (2007), while fixation times vary greatly between task types, the shortest fixations observed averaged 150 ms. Since off-road glances in this study include both the saccade to and away from the forward roadway, glance duration values less than 200 ms were judged physiologically implausible and hence removed. Also, glances longer than 3000 ms were removed to avoid inflating eyes-off-road glance durations due to measurement error. Finally, 85th percentile off-road glance duration values for each participant and task repetition were calculated.

Results

The 85th percentile off-road glance duration values for each participant and task is presented in Table 4.

Table 4 85th percentile off-road glance duration values for each participant and task. Participants are ordered by mean value. Values exceeding 2.0 seconds are highlighted.

TP	Radio 1	Phone 1	Settings 1	Radio 2	Phone 2	Settings 2	Radio 3	Phone 3	Settings 3	Mean
5	0,88	1,48	1,50	0,93	1,50	1,10	1,15	1,28	1,13	1,21
7	1,10	1,45	1,30	1,33	1,40	1,23	1,08	1,35	1,28	1,28
2	1,18	1,80	1,43	1,43	1,48	1,28	1,03	1,33	1,48	1,38
1	1,63	1,65	1,20	0,68	2,00	1,58	1,28	1,53	1,13	1,41
10	1,23	1,65	1,53	1,48	1,98	1,53	1,28	1,63	1,43	1,52
14	1,50	1,68	1,43	1,43	1,60	1,33	1,50	1,75	1,53	1,53
11	1,25	1,73	1,83	1,65	1,43	1,50	1,45	1,40	1,80	1,56
12	1,48	1,83	1,95	1,63	1,65	1,63	1,63	1,98	1,53	1,70
13	1,43	2,48	1,73	1,80	1,78	1,70	1,25	1,83	1,68	1,74
8	1,45	1,43	1,90	2,08	2,10	1,60	1,83	1,78	2,18	1,81
16	1,70	2,08	2,13	1,50	2,08	2,18	1,83	1,65	1,85	1,89
15	2,25	2,18	2,00	1,93	1,93	1,45	1,75	1,75	1,78	1,89
6	1,85	1,75	1,83	1,63	2,10	2,40	1,58	2,63	1,35	1,90
4	1,80	2,55	2,53	2,00	2,00	1,80	1,80	1,80	1,70	2,00
9	1,75	2,30	2,00	1,88	2,48	2,05	1,50	2,13	2,15	2,03
3	2,25	2,65	2,43	2,30	2,30	2,70	2,90	1,85	2,45	2,43

Figures 2 shows each driver's overall mean 85th percentile off-road glance duration value (i.e. for all tasks and trials). Participants are ordered by mean value.

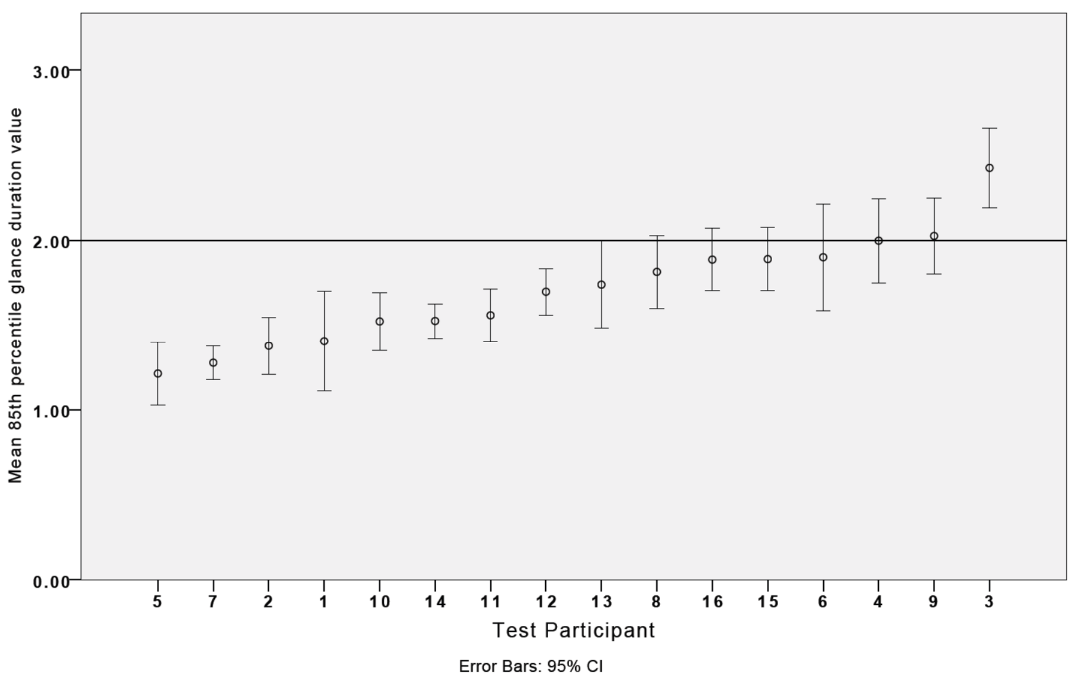

Figure 2 **85th percentile off-road glance duration values for the radio task, ordered by the participants' mean values.**

The data was subjected to a 3 * 3 mixed ANOVA with Task type (Radio, Phone, Sound Settings) as between subjects factor and Repetition (1, 2, 3) as within-subjects factor. To test for correlation between the mean response times in each round of the trail-making test and 85th percentile off-road glance durations, a two-tailed Pearson correlation test was performed. The ANOVA showed no main effect of Task type or Repetition, though the p-value for the latter was comparatively low ($p = 0.088$).

The pattern for repetition can be seen in Figure 3, where values for the Phone and Settings tasks seem to decrease over repetitions, while the values for the Radio task are more stable. In a follow up analysis where the radio task was excluded, there was indeed a main effect of repetition ($F(2,60) = 3.61$, $p = .033$), see figure 3.

In terms of drivers' performance on the trail-making test, there were no significant correlations between the mean response times in either part A and B of the Trail Making Test and the 85th percentile off-road glance durations for the three in-vehicle system tasks.

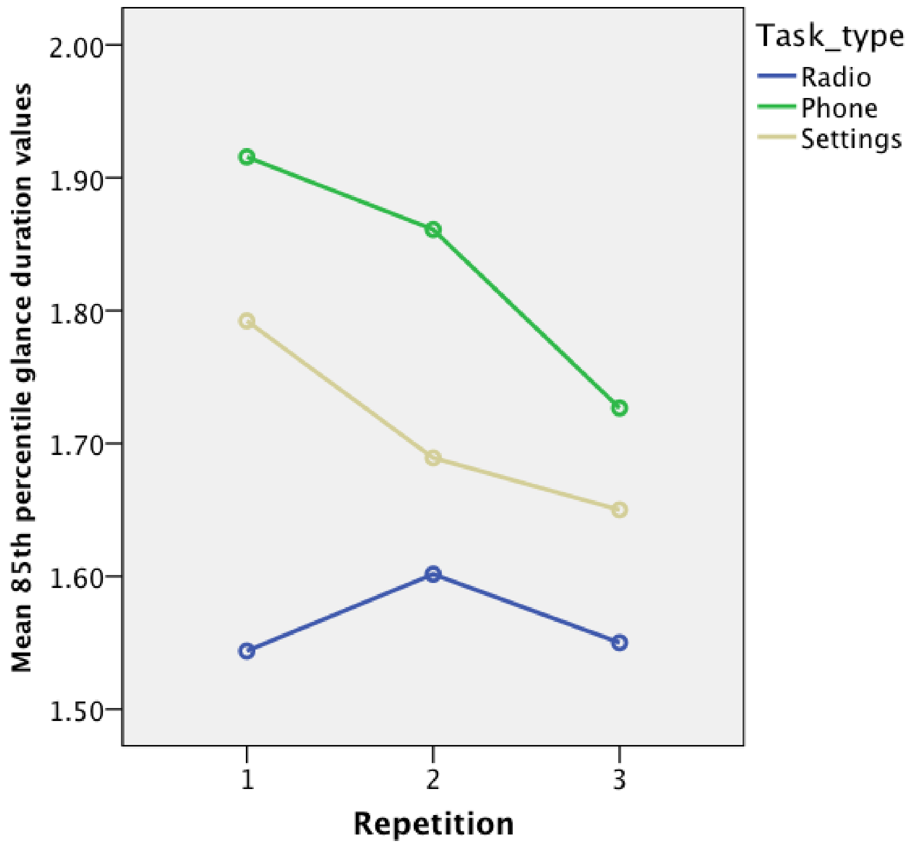

Figure 3 **Mean 85th percentile off-road glance duration for each task and occasion**

Discussion

One goal of this study was to investigate the prevalence of "long glancers" among randomly recruited test participants. In relation to the test criterion proposed by NHTSA, the current study show that seven out of sixteen participants had 85th percentile off-road glance duration values exceeding 2.0 seconds for one or more tasks.

Moreover, the limit was often repeatedly exceeded by the same participant (see table 4). In Ljung Aust et al. (2013), 1 in 6 test participants were labelled “long glancers”. The current study suggests similar numbers, i.e. slightly more than 1 in 6.

Some failures to stay below 2.0 seconds are surely attributable to poor interaction design in the infotainment mock-up. However, the fact that “long glancers” seem to be quite prevalent both in road and simulator testing gives pause for thought. For example, assume that two identical in-vehicle tasks were to be tested. If the sampling is random, then one test group might get five “long glancers” while another group gets none. In that case, the task being tested is likely to pass the 85th percentile criterion in one group but fail in the other. Such an outcome would defeat the purpose of similar compliance testing. The 85th percentile criterion thus seems to need revision to better allow for this natural variability.

The second goal of the study was to assess whether drivers’ visual performance capacity or limited task practice might explain this between driver variability. Here, previous studies found correlation between drivers’ performance on the Trail Making Test and off-road glance durations (Wikman and Summala, 2005), however, no such effects were present in this study. An explanation for this might be that those previous correlations were found on measures of central tendency (Wikman and Summala, 2005), while this study focused on the longer driver glances, i.e. the 85th percentile off-road glance duration values. This result also suggests that those longer glances might not depend on drivers’ performance capacity for visual search speed and flexibility. Instead, other underlying individual factors such as risk taking propensity (Donmez, Boyle and Lee, 2010) or sensitivity to forward view uncertainty build-up (Wierwille, 1993) might be at play.

As can be seen in figure 2, the individual differences in average 85th percentile glance duration values are quite large, with the longest average being twice as long as the shortest. This corroborates the findings of Ljung Aust et al. (2013), where the variation also was small within drivers compared to between drivers.

When it comes to task repetition, the learning process seems to influence the longer glance durations for some tasks. In this study 85th percentile glance durations shortened with repetition of the Phone and Settings tasks. This occurred even if drivers had practiced until they were comfortable performing the tasks prior to the trial. Hence, task practice while driving seems more efficient than practice while standing still. This was acknowledged in the amendment of the NHTSA guideline (NHTSA, 2013), where pre-trial practice was extended to include also practice while driving before the actual data collection trial.

While the values in Figure 3 keep decreasing for the Phone and Settings tasks, they seem rather stable for the Radio task. This is an interesting result. One might hypothesize that if test participants had been given further trials, values for Phone and Settings would level out rather than decrease further. If and when this levelling out occurs, and whether any difference between the tasks remain at that point, are all very interesting topics for future studies, and again stresses the fact that compliance test outcome might depend on how much pre-trial practice participants get.

As for the possible explanations for between driver off road glance duration variability, individual strategy differences seem more viable than underlying performance capacity or learning effects over repeated trials, especially given the lack of correlation with the Trail Making Test. Moreover, the type of task does not seem to substantially affect this strategy. If corroborated in further studies, this is also the most troubling result. Controlling for performance capacity or pre-trial practice seems quite feasible, but controlling for individual strategies such as risk taking propensity seems more difficult. Identifying and controlling for individual behavioural strategies thus seems to be a key issue to achieve robust and precise compliance testing in the future.

Limitations

The largest limitation of this study is the loss of test participants due to poor eye-tracking quality. However, the most likely explanation for this loss is that the eye-tracker software has difficulties recognizing distinguishing features in some people's faces. This means that the data loss can be viewed as random as long as the facial features of a participant does not correlate with his/her visual attention sharing strategy. Another limitation is the filtering of the eye-tracker data. The current filter did make assumptions about where participants were most likely to look while performing in-vehicle system tasks. For example, when there were small gaps in gazes directed toward the tablet computer, it was assumed that the participants did look at the tablet computer. To assess this risk, the eye-tracker data was compared to drivers glance behaviour as recorded on the videos from the tests. These comparisons indicate that the filter was set up correctly.

Conclusion

The current study looked at 85th percentile glance duration values for drivers performing typical in-vehicle infotainment tasks. These were found to be more varied between drivers than within drivers. Moreover, the prevalence of drivers with long off-road glance durations suggest that tasks tested according to the proposed NHTSA manual-visual design guidelines may fail to meet the proposed 85th percentile glance duration criterion, simply due to normal variability in the driver population rather than poor HMI design. This is contrary to the guideline purpose and suggests that the criterion need to be reformulated. Furthermore, compared to underlying driver performance capacity or test procedure artefacts, differences in individual strategies seem a more likely explanation for the large between driver variability. Finding ways of identifying and controlling for individual behavioural strategies during compliance testing might thus be essential to robustness and precision in future compliance testing of multitasking drivers.

References

Bowie, C. R., Harvey, P. D. (2006). Administration and interpretation of the Trail Making Test. *Nature Protocols, 1*(5), 2277-2281.

Broström, R., Bengtsson, P., & Axelsson, J. (2011). Correlation between safety assessments in the driver–car interaction design process. *Applied Ergonomics, 42(4)*, 575-582.

Broström, R., & Davidsson, S. (2012). Towards a model to interpret driver behaviour in terms of mismatch between real world complexity and invested effort. *Work: A Journal of Prevention, Assessment and Rehabilitation, 41*, 5068-5074.

Crowe, S. F. (1998). The differential contribution of mental tracking, cognitive flexibility, visual search, and motor speed to performance on Parts A and B of the Trail Making Test. *Journal of Clinical Psychology, 54*(5), 585-591.

Dingus, T.A., Klauer, S.G., Neale, V. L., Petersen, A. et al. 2006. "The 100-Car Naturalistic Driving Study, Phase II – Results of the 100-Car Field Experiment." Cambridge: U.S. Department of Transportation, John A. Volpe National Transportation Systems Center.

Alliance of Automobile Manufacturers. 2006. "Statement of Principles, Criteria and Verification Procedures on Driver-Interactions with Advanced In-Vehicle Information and Communication Systems", Driver Focus-Telematics Working Group, Washington, DC., June 26, 2006 update.

Emerson, J. L., Johnson, A. M., Dawson, J. D., Uc, E. Y., Anderson, S. W., Rizzo, M. (2012). Predictors of driving outcomes in advancing age. *Psychology and Aging, 27*(3), 550-559.

European Commission. 2008. "Commission Recommendation of 26 May 2008 on Safe and Efficient In-Vehicle Information and Communication Systems; Update of the European Statement of Principles on Human-Machine Interfaces".

Hargrave, D. D., Nupp, J. M., Erickson, R. J. (2012). Two brief measures of executive function in the prediction of driving ability after acquired brain injury. *Neuropsychological Rehabilitation, 22*(4), 489-500.

ISO standard 15007-1:2002. "Road vehicles – Measurement of driver visual behavior with respect to transport information and control systems Part 1: Definitions and parameters".

JAMA. 2004. *Guideline for In-Vehicle Display Systems, Version 3.0*. Japan Automobile Manufacturers Association, Tokyo, Japan, August 2004.

Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J., & Ramsey, D. J. 2006. "The impact of driver inattention on near-crash/crash risk: An analysis using the 100-Car Naturalistic Driving Study data." Blacksburg, VA: Virginia Tech Transportation Institute, 2006.

Land, M. F. "Eye movements and the control of actions in everyday life. *Progress in Retinal and Eye Research*, 25(3), 296-324, 2006.

Liang, Y., Lee, J.D., Yekhshatyan, L. 2012. "How dangerous is looking away from the road? Algorithms predict crash risk from glance patterns in naturalistic driving". Published online before print, *Human Factors: The Journal of the Human Factors and Ergonomics Society*, June 15, 2012.

Ljung Aust, M., Dombrovskis, S., Kovaceva, J., Svanberg, B. & Ivarsson, J. (2013) "An Empirically Based Suggestion for Reformulating the Glance Duration Criteria in NHTSA's Visual-Manual Interaction Guidelines", in the proceedings of SAE 2013 World Congress, 15-18 April, Detroit, USA. Paper no 2013-01-0444.

NCSA (2012) "Distracted Driving 2010." In Traffic Safety Facts - Research Note. National Center for Statistics and Analysis of the National Traffic Highway Safety Administration, Washington D.C.

NHTSA (2012) Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices, Federal Register, / Vol. 77, No. 37 / Notices / Docket No. NHTSA–2010–0053, Department of Transportation. Available at http://www.gpo.gov/fdsys/pkg/FR-2012-02-24/pdf/2012-4017.pdf

NHTSA. 2012. "Visual-Manual NHTSA Driver Distraction Guidelines for in-Vehicle Electronic Devices." National Traffic Highway Safety Administration, Department of Transportation, Washington, D.C. Federal Register, Vol. 77, No. 37, February 24, 2012. Accessed 120226 at http://www.gpo.gov/fdsys/pkg/FR-2012-02-24/pdf/2012- 4017.pdf

Rayner, K. 1998. "Eye movements in reading and information processing: 20 years of research". *Psychological Bulletin* 124, 372–422.

Smart Eye. 2013. Smart Eye Pro 2-8 cameras. Retrieved 20130715 from http://www. smarteye.se/productseye-trackerssimulators/smart-eye-pro-2-6-cameras.

Summala, H., Etholén, T., Leino, N., Niskakangas, M., Laine, M. & Saarinen, S. 2008. FR-TMT: Visuospatial (working) memory in a computerized Trail-Making test. Poster presented at the *Psykologia 2008 Congress*, August 20-22, Helsinki.

Victor, T. and Dozza, M. "Timing matters: Visual behavior and crash risk in the 100-Car online data". Presentation given at the 2nd International Conference on Driver Distraction and Inattention, Gothenburg, Sweden, Sept 5-7, 2011. Accessed 120125 at http://www.chalmers.se/safer/ddi2011-en/

Wierwille, W. W. (1993). Visual and manual demands of in-car controls and displays. In B. Peacock & W. Karwowski (Eds.), Automotive ergonomics (pp. 299–320). Philadelphia, PA: Taylor & Francis.

Wikman, A. S., & Summala, H. (2005). Aging and time-sharing in highway driving. *Optometry & Vision Science, 82*(8), 716-723.