Measuring the distraction of alternative list-scrolling techniques when using touchscreen displays in vehicles

David R. Large, Gary E Burnett, Elizabeth Crundall, Glyn Lawson and Sarah-Anne De-Kremer

Human Factors Research Group, University of Nottingham, UK

Abstract

Interactive touchscreen displays are increasingly prevalent in cars, providing direct-manipulation access to information, communication and entertainment services. However, touchscreens are inherently associated with high visual demand and often require physical dexterity to manipulate them. Touchscreens may therefore distract drivers if used while driving. A simulator study investigated the impact of using three existing list-scrolling techniques on driving performance and preferences while driving in a medium-fidelity, fixed-based driving simulator. Twenty experienced drivers used page-by-page, flick-scrolling and page-swiping techniques to locate specified words within structured, vertical word lists displayed on a touchscreen located in the centre console of a right-hand drive car. Page-by-page performed worst during the study – objectively, it was associated with the longest task-times and the highest number of off-road glances and subjectively, was least preferred by participants both before and after driving. Flickscroll and pageswipe performed equally well with respect to task completion time, glance behaviour and driving performance. Drivers preferred flick-scroll before driving but favoured page-swipe afterwards as it was perceived to be “easiest to use” and “less distracting.” Page-swipe offers the benefits of both flick-scroll (large interaction area) and page-by-page (displays discrete ‘chunks’ of information). It may therefore be more easily incorporated into the self-paced nature of driving. Further research is required to quantify the perceived benefits.

Introduction

Drivers and passengers demand an increasingly varied array of dynamic information, communication and entertainment services within their vehicles. This is ideally suited to the form and function of touchscreen interfaces. Touchscreens provide a large, flexible visual display, require no peripheral devices such as keyboards, and allow the direct manipulation of information using interaction techniques that may be familiar to drivers from non-automotive contexts. Consequently, touchscreen devices are increasingly incorporated within car dashboards, where they may be employed to display and navigate through structured lists of driver and driving-related information such as vehicle settings, navigational commands, music tracks, phone contacts, etc. However, the direct transfer of these devices to the driving domain may be inappropriate. Touchscreens, and the interaction techniques that they employ, are inherently associated with high visual demand and often require physical dexterity for successful manipulation. Using touchscreens while driving may therefore overload or distract drivers and this is likely to have a detrimental effect on driving performance and vehicle control, resulting in an elevated risk to drivers and other road users.

Transfer of Touchscreens to the Automotive Domain

The rapid development of touchscreen technology has occurred largely within non-automotive domains (e.g. mobile phones and tablet computers). This has resulted in a corpus of features, ‘best-practice’ interaction techniques and ergonomic design recommendations that are ideally suited to a sedentary (non-automotive) context. For instance, multi-touch gestures may be employed that require the presence of two or more points of contact with the surface (e.g. pinch-to-zoom, anchor-and-rotate) and provide visually captivating feedback. Touchscreen interactions also often rely on strong visual clues within the content displayed on screen or may provide subtle communication provided through visual design metaphors. For example virtual user-interface (UI) elements are often rendered on-screen to mimic their real world counterparts, including buttons that ‘depress’ when they are touched, pages of a book that ‘turn’ when swiped, or lists that ‘scroll’ to allow users to move through them.

Furthermore, interactions with smartphones and tablets are fundamentally determined by ergonomic and anthropometric issues and these are based on the expected configuration during use. For instance, smartphones may be held and operated using the same (dominant or preferred) hand. Consequently, smartphone interface elements are typically located at the bottom of the screen on smartphones (‘the thumb zone’) so that the interface is navigable using just a thumb. Similarly, the active zone of a tablet interface reflects the likely ergonomic configuration when using the device. In contrast to smartphones, tablets may be held and used in a number of different configurations (e.g. embraced like a book, held like a clipboard, or propped up against a surface or using a stand) and therefore the location of UI elements may depend on the application. Intuitively, users will interact with a tablet using their dominant hand, while their other hand supports the device. However, within car interiors, physical space limitations dictate that a touchscreen is likely to be positioned within the centre console. Consequently, drivers of right-hand drive cars (in UK) are, in the majority of cases, required to use their non-preferred or non-dominant hands to interact with the touchscreen.

In a sedentary context, interacting with a touchscreen device typically constitutes the primary task and may therefore subsume the user’s full visual attention without consequence. However, within a vehicle, drivers’ attention should not be averted from the primary task of driving. Given the visual cues/feedback and the physical dexterity required to manipulate these devices (especially important for those drivers using their non-dominant hand), it is probable that some of the existing interaction techniques may divert drivers’ attention away from driving-related activities that are critical for safe driving (Lee et al. 2008). This is likely to have deleterious effects on steering (Liang and Lee 2010), maintenance of lane position maintenance (Land and Horwood 1995) and hazard identification (Liang and Lee, 2010, Crundall et al. 2012) ultimately leading to greater crash risk (NHTSA 2006).

The current study aimed to investigate the impact of using three existing list-scrolling techniques (page-by-page buttons, flick-scrolling and page-swiping) on driving performance and driver behaviour. One-dimensional, structured, vertical word lists were displayed on a 9.7-inch LED-backlit capacitive touchscreen (Apple iPad 2) positioned in landscape orientation in the centre console of a right-hand drive car. Drivers were required to use each of the three techniques to move through the lists and select specified words while driving on a motorway in a medium-fidelity, fixed-based driving simulator.

List Scrolling

Three alternative list-scrolling methods were used during the study – page-by-page (PB), flick-scrolling (FS) and page-swipe (PS) (see Figure 1). The methods were chosen as they were familiar, well-known techniques already commonly used in touchscreen devices. They differed based on the target area of active UI elements ('interaction area') and the presentation of information ('chunking technique').

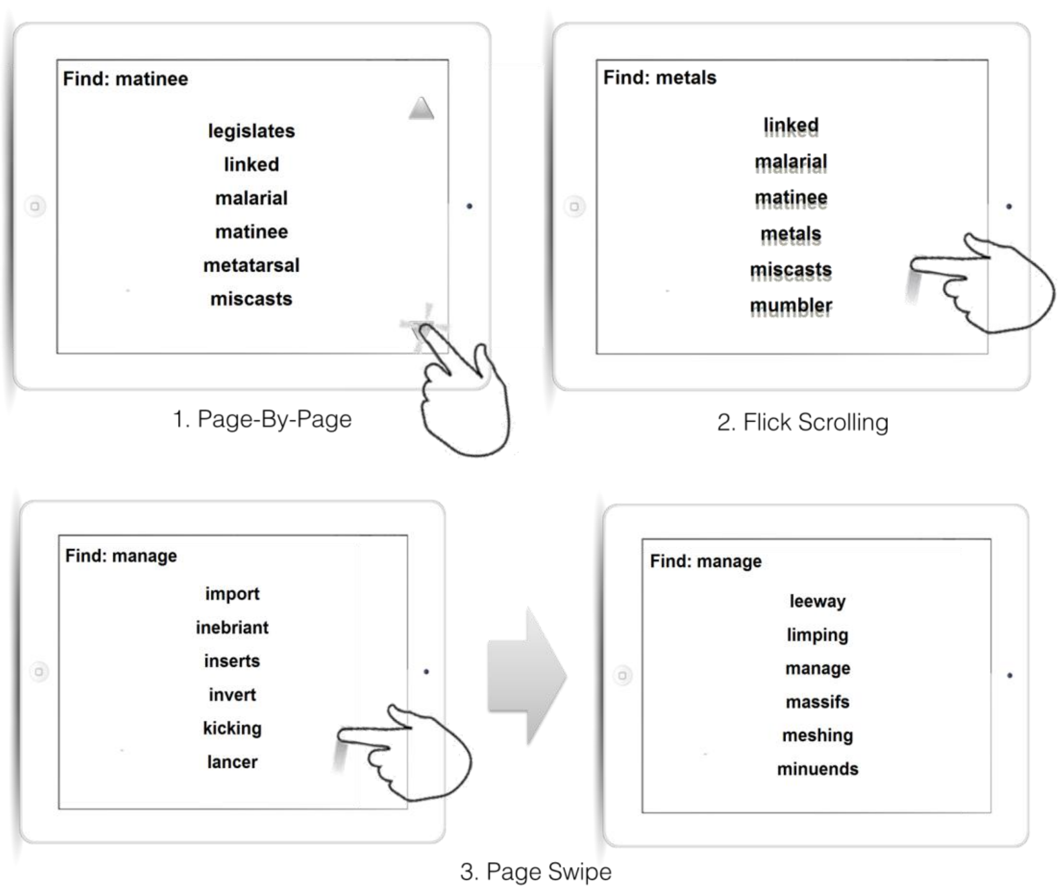

Figure 1 The three different list-scrolling techniques used during the study

The page-by-page buttons method was included in the study in order to compare newer scrolling techniques to more traditional methods for moving through lists. This technique allowed users to move through discreet 'chunks' (or screenfuls) of each list by visually locating and touching (or 'pressing') 'down' or 'up' arrow icons displayed next to the list.

The flick-scrolling method (also commonly referred to as momentum-based scrolling or kinetic scrolling) was selected based on its popularity in current mobile touchscreen technology (smartphone and tablet). This technique required users to move through the list by 'flicking' it in the counter-direction of travel (i.e. flicking the list up apparently moves items off the top of the screen and reveals new items below, and vice versa). The process is dynamic and visual feedback suggests that users are moving through the list. In the study, flicking gestures could be made anywhere on the visible screen and were not restricted to a limited active zone. Users were also able to build up speed or momentum while moving through the list by repeatedly making gestures in quick succession, i.e. re-flicking before the list has come to a rest. In this situation, the list will naturally come to rest at an uncontrolled and unspecified position.

The page-swiping technique was included as it provided a hybrid of the two aforementioned methods. In this technique, users were able to move through the lists using the same ‘flick’ action as the flick-scrolling method. However, a single flick only revealed the next ‘chunk’ of items and did not move the list any further. Again, flick gestures could be made anywhere on the visible screen and were not restricted to a designated active zone.

Method

Participants

Twenty people were recruited for the study (12 male and 8 female; mean age 32.4 years, range 21 to 62 years). All participants were experienced and active drivers (mean time with full driving licence: 13.25 years, mean current annual mileage: 7220 miles). Participants gave written informed consent before taking part and were reimbursed with high street shopping vouchers for their time.

Design

A repeated measures design was used, with list-scrolling method (page-by-page, flick-scrolling and page-swiping) and list length (short, medium and long) as the independent variables. Dependent variables were task completion time, number and duration of off-road glances, mean and standard deviation of speed, lateral lane position and headway to a lead vehicle. In order to measure variations in speed and longitudinal position, participants were asked to follow a lead vehicle at a distance that they deemed to be ‘safe’ and ‘appropriate’ during the drive. Participants were also asked to provide subjective preference ratings for each technique before and after driving.

Apparatus and Procedure

The study took place in a fixed-based, medium fidelity driving simulator using STISIM (version 2) software (see Figure 2). The simulator comprised the front half of a 2001 right-hand drive Honda Civic SE car positioned within a curved screen affording an approximate 270° view. The driving scenario was projected onto the screen using three overhead projectors, with rear views relayed to the side mirrors using video cameras and LCD displays. A fourth overhead projector was used to project the rear view to a screen situated behind the car, which could be seen by the driver using the existing rear-view mirror. Drivers were able to interact with the car and scenario using an authentic steering wheel which provided force feedback, accelerator, brake and clutch pedals and steering column controls, such as indicators, situated within the car. The simulated driving scenario was designed to replicate a generic UK motorway populated with a medium density of traffic. Participants began on the motorway slip-road and were asked to join the motorway behind a lead vehicle and to follow that vehicle at a distance that they felt was ‘safe and appropriate’. In all other respects, participants were advised to drive as they would in the real world with safety as a priority. In order to regulate primary task demand the motorway followed a straight course and the lead car remained in lane one throughout the entire drive. On average, participants took approximately eight minutes to complete the drive.

Figure 2 Participant interacting with touchscreen while driving in simulator

Vehicle control data were recorded at 0.1 second intervals throughout the drive using the STISIM data logging facility. Audio-visual recordings of the participant and driving scenario were also made during the experiment using four miniature cameras strategically positioned for non-obtrusive data capture.

Participants' glance behaviour was recorded using an ETG (Eye Tracking Glasses) system from SensoMotoric Instruments collecting binocular gaze data at 30Hz. This was overlaid onto a scene video recorded from the participant's point of view to provide a video record of where the participant was looking over the time course of the experiment. For the purpose of analysis, glances were categorised as either 'on-road' or 'off-road'. On-road glances are defined as those associated with normal driving activities, including those directed to the forward driving scene, glances to mirrors and to the dashboard instrument cluster (e.g. to view speedometer). Off-road glances are defined as those specifically directed towards the touchscreen displaying the word lists. The duration of off-road glances included both the fixation and the saccade to and from the touchscreen.

Word lists were presented to participants using a 9.7-inch LED-backlit capacitive touchscreen (Apple iPad2) located in the centre console of the car. All word lists were ordered alphabetically, ranging from 'a' to 'z' and comprised common English words with British spellings selected from an online dictionary. The words were presented in lower case and rendered using 22-point Helvetica font. All lists were centre-justified on the screen. The word-lists were coded using HTML and rendered on-screen using the Safari web-browser. Task-time was captured client-side using Javascript and saved to a server-side data file using PHP script.

Target words appeared at varying positions within the lists, thereby representing short (2-4 pages), medium (6-8 pages) and long (10-12 pages) lists. Each visible 'page' contained six words. For page-by-page and page-swipe techniques, the target words appeared at different locations on the visual portion of the lists.

Participants were provided with the target word at the start of each task, expressed as an instruction, for example, "Find: metals." The target word remained visible on screen for the duration of each task. Different word lists and target words were used for each task. Selecting the target word by touching it ended that task. Participants always began at the top of a list.

Extensive training was provided before driving for each technique to ensure skilled performance – participants were instructed how to use each technique and navigated through five short, five medium and five long lists for each interaction technique. In order to minimise driving time in the simulator, participants were presented with one example of each list length for each list scrolling technique while driving. Subjective preference ratings were provided after training (before driving) and after driving.

Results

Dependent variables were analysed using repeated measures ANOVAs. Any significant interactions were analysed using simple main effects analysis. All significant effects were explored further using pairwise comparisons with Bonferroni correction.

Task Completion Time

A repeated measures ANOVA comparing the three list lengths across the three different list-scrolling techniques revealed a significant main effect of technique, $F(2,30) = 10.03$; $MSE = 9.89$; $p<0.001$. Participants were significantly slower with the page-by-page technique than the other two techniques ($p<0.01$). A main effect of list length, $F(2,30) = 100.58$; $MSE = 6.18$; $p<0.001$, revealed an increase in task time with increasing list length and there were significant differences between all three list lengths ($p<0.001$).

However, there was also a significant interaction between technique and list length, $F(4,60) = 2.93$; $MSE = 10.79$; $p<0.05$, shown in Figure 3. Analysis of simple main effects confirmed that there was only an effect of technique for medium lists, $F(2,34) = 3.30$; $MSE = 7.71$; $p<0.05$), and long lists, $F(2,34) = 7.62$; $MSE = 18.23$; $p<0.01$. For medium and long lists, participants were significantly slower using the page-by-page technique than the flick scroll technique ($p<0.01$). Furthermore, when participants used the page-by-page technique, there was a consistent increase in task time with increasing list length ($p<0.01$), but when participants used the flick scroll or pageswipe techniques, there was only a significant increase in task time between short and medium lists ($p<0.01$), but not between medium and long lists.

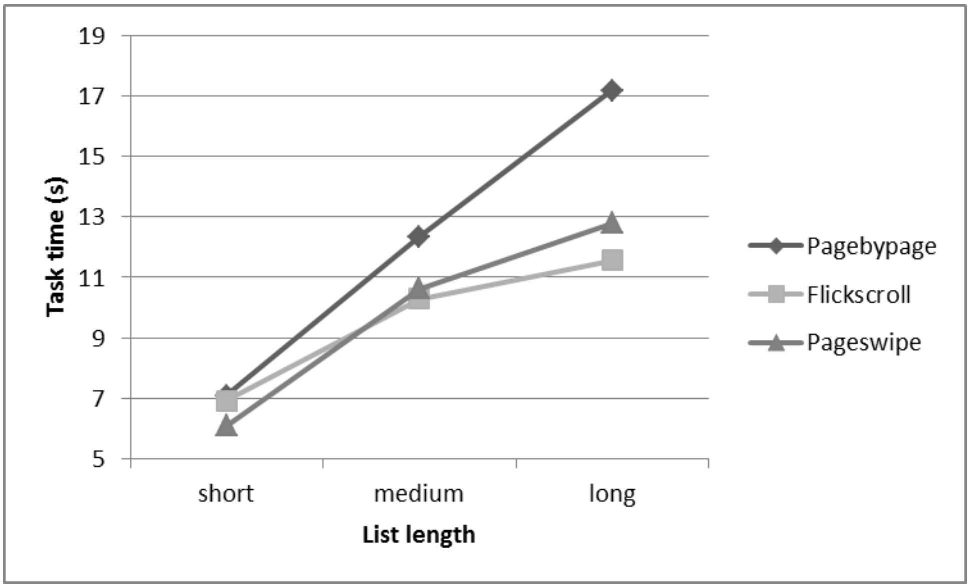

Figure 3 Estimated marginal means of task completion time against list length for the three list-scrolling techniques

Glance Behaviour

A summary of off-road glances can be seen in Table 1 for the three list scrolling techniques: page-by-page (PB), flickscroll (FS) and pageswipe (PS).

Table 1 Glance behaviour while driving

	Short list			Medium list			Long list		
	PB	FS	PS	PB	FS	PS	PB	FS	PS
Mean glance duration (s)	1.4	1.3	1.6	1.1	1.2	1.1	1.1	1.1	1.2
Mean number of glances	4.6	4.7	4.2	7.8	6.2	6.6	9.9	7.6	7.4
Mean total glance time (s)	5.8	5.5	5.8	8.0	6.9	6.8	10.0	7.9	8.2
Mean no. of glances > 2s	0.44	0.50	0.69	0.56	0.50	0.38	0.38	0.56	0.69

A repeated measures ANOVA comparing the three list lengths across the three different techniques revealed a significant main effect of list length on mean glance duration, $F(2,30) = 15.52$; $MSE = .07$; $p<0.001$. Mean glance duration was significantly longer for short lists than for medium lists ($p<0.001$) or long lists ($p<0.01$), but there was no significant difference between medium and long lists. There was no effect of technique and no interaction for mean glance duration.

There was also a significant effect of list length on number of glances, $F(2,30) = 68.61$; $MSE = 2.56$; $p<0.001$. Unsurprisingly, participants made the fewest glances on short lists, followed by medium lists, then long lists, and all comparisons were statistically significant ($p<0.001$). More interestingly, there was also a main effect of technique, $F(2,30) = 6.92$; $MSE = 4.12$; $p<0.01$, which revealed that participants made significantly more glances when using page-by-page than when they used either of the other techniques ($p<0.016$). However, there was also an interaction between technique and list length, $F(4,60) = 2.65$; $MSE = 2.72$; $p<0.05$), which revealed that the differences between techniques were only significant for long lists, $F(2,30) = 8.61$; $MSE = 3.50$; $p<0.01$. In this situation, page-by-page produced significantly more glances than the other two techniques ($p<0.01$) (see Figure 4).

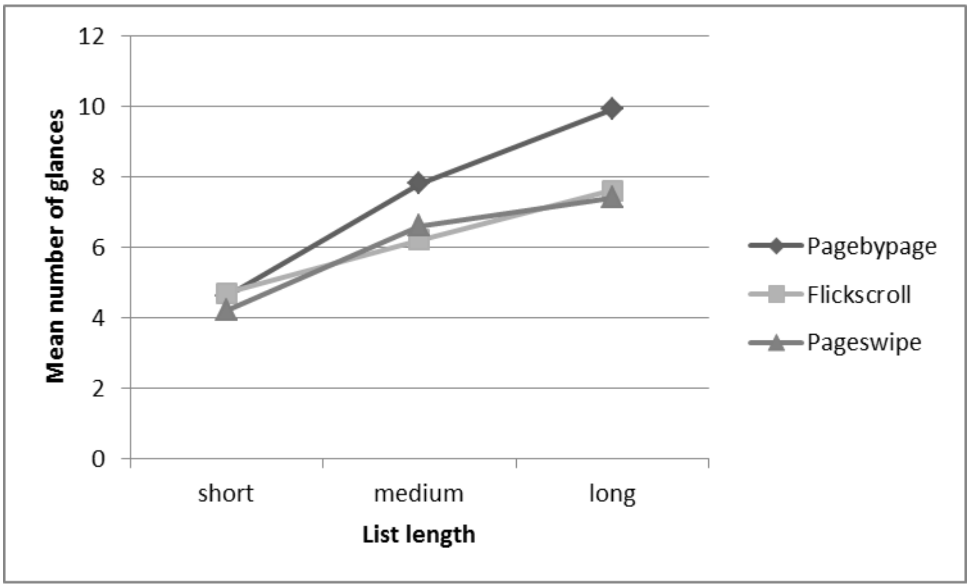

Figure 4 Mean number of glances plotted against list length for the three list-scrolling techniques

Driving Performance

A repeated measures ANOVA comparing the three different techniques revealed a significant main effect of technique on standard deviation of headway, $F(2,30) = 6.89$; $MSE = 421.22$; $p<0.01$. The page-by-page technique was associated with the largest variation in headway, followed by the flick scroll technique, then the pageswipe technique. Differences between the flick scroll technique and the other techniques were approaching significance ($p=0.05$ in both cases), but the only statistically significant difference was between the page-by-page and page swipe techniques ($p<0.01$) (see Figure 5). There were no significant effects of technique on any of the other driving measures with the current sample (mean and standard deviation of speed, standard deviation of lane position and mean headway).

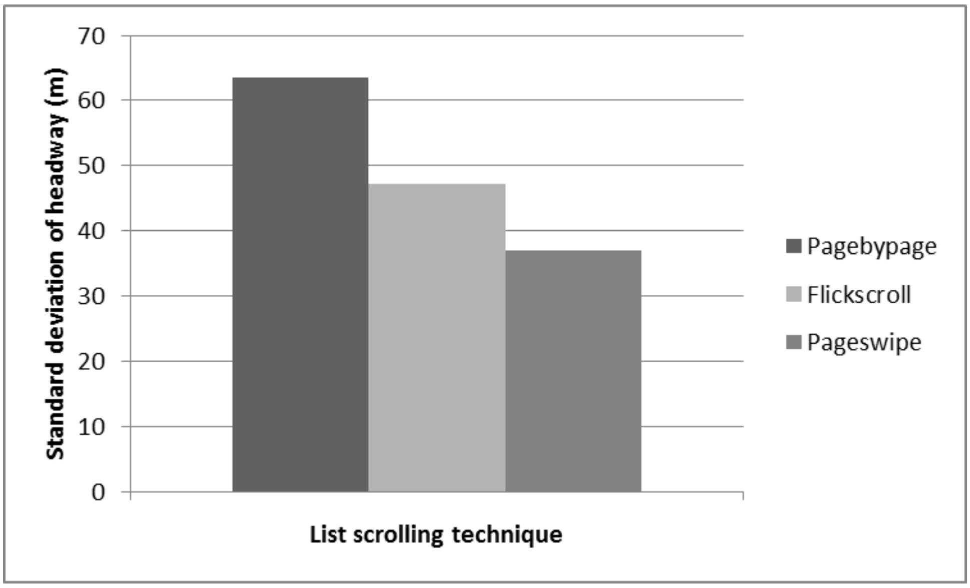

Figure 5 Estimated marginal means of standard deviation of headway for each list-scrolling technique

Subjective Ratings

Participants were asked to rank each technique based on their preferences (1=most preferred and 3=least preferred). A Friedman Test was carried out to compare the rankings. This revealed that, before driving, there were significant differences between rankings for each of the techniques (Chi Square = 7.7; df = 2; p<0.05). Further analysis using Wilcoxon Signed Rank Tests (with Bonferroni correction to adjust for multiple comparisons) revealed that, before driving, flick scroll was ranked more favourably than the page-by-page (Z = 2.55; p<0.05) (see Table 2 and Figure 6).

Table 2 Preferences before and after driving

	After driving		Before driving	
	Median Rank	Mean Rank	Median Rank	Mean Rank
Page-by-page	2	2.42	3	2.47
Flickscroll	2	2.00	1	1.58
Pageswipe	1	1.58	2	1.95

Subjective preference ratings made after driving were also significantly different (Chi Square = 6.7; df = 2; p<0.05). However, in this situation, the pageswipe technique was ranked more favourably than page-by-page (Z = 2.48; p<0.05) (see Table 2). After driving, participants stated that they preferred the pageswipe technique as it was “easiest to use” and “distracted them least” while driving.

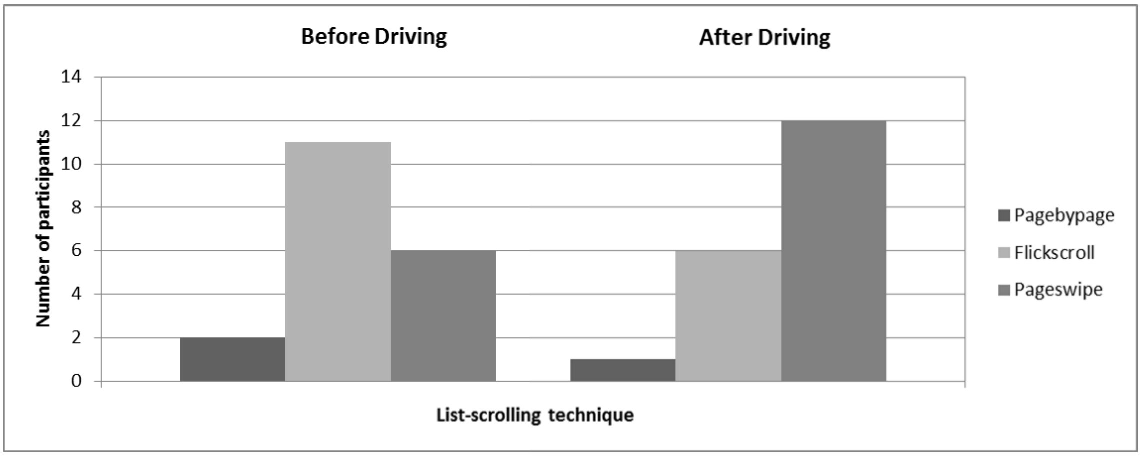

Figure 6 Most preferred devices before and after driving

Discussion

The study employed three different list-scrolling techniques (page-by-page, flick-scrolling and page-swiping) to move through one-dimensional, structured, vertical word lists displayed on an interactive capacitive touchscreen and investigated the relative effects of these on driving performance/behaviour and subjective preferences. The methods were familiar, well-known techniques already used by touchscreen devices. The results include data from objective and subjective measures, including secondary task times, driving performance, glance behaviour and subjective preferences. It therefore provides a better comparison of methods than would be obtained from one form of data alone and consequently benefits from greater external validity (Lee, et al., 2008).

The longer task times associated with the page-by-page technique reflect the regimented strategy that is required to move through lists using this technique. People are required to locate and ‘press’ (touch) a specific interaction area in order to move through and preview consecutive ‘chunks’ of the list. The technique therefore requires greater accuracy of finger placement than other techniques and this affects glance behaviour. Furthermore, given the smooth glass surface of the touchscreen, the on-screen buttons lack the tactile feedback associated with traditional knobs, switches and buttons allowing them to be located without averting one’s eyes from the road. This may explain why participants made significantly more glances when using page-by-page to negotiate longer lists while driving. The page-by-page technique was also associated with decrements in driving performance, demonstrated by the standard deviation of headway. Variations in headway suggest increased workload as drivers slow down to conduct the task and then speed up to resume their position behind the lead vehicle. This also corresponds with the longer task times and additional glances and suggests that page-by-page demands greater attention from drivers than the other techniques thereby reducing the attention that they are able to allocate on vehicle control. It may also explain why page-by-page was least preferred by participants.

In contrast, the flickscroll and pageswipe techniques offer advantages for medium and long lists. Both techniques allow users to move through lists more quickly and with less visual load than page-by-page – there were no bounded interaction elements and therefore gestures could be made anywhere on screen. Consequently, task completion times were shorter. However, although it was evident that the page-by-page technique performed worst during the study – both objectively and subjectively – it appears that flickscroll and pageswipe both performed equally well with respect to task completion time, glance behaviour and driving performance. Indeed, the analysis revealed negligible differences between these two methods. Nonetheless, drivers felt that flickscroll was more distracting and difficult to use while driving and stated that they therefore preferred pageswipe.

As it was not possible to differentiate flickscroll and pageswipe based on the objective performance measures, video records were used to qualitatively examine the search strategies employed by participants when using each of these techniques. The videos revealed that participants appeared to employ different strategies depending on whether they were using flickscroll or pageswipe. When using flickscroll, participants built up list-momentum to reach the general vicinity of the target word quickly and then 'fine-tuned' the list. As list items often continued to move even after drivers had finished interacting with the touchscreen and returned their attention to the driving environment, drivers may have made incorrect expectations of which items would be displayed when their gaze returned to the screen. Therefore, longer glances may have been required when resuming the task (Ratwani et al. 2007). Searches using this technique may therefore have been extended overall by the more demanding list-reorientation and fine-tuning required towards the end of each task. In contrast, when using pageswipe, participants progressed through the lists at a steadier and more controlled pace than flickscroll, albeit notably quicker than page-by-page, and there was little evidence from the videos of the need to 'fine-tune' towards the end of the search task. Consequently, the pattern of glances differed between techniques, though this had not been immediately apparent from the glance measures originally analysed. Therefore, although task-times, driving performance and overall glance behaviour were similar between these techniques, participants perceived pageswipe as less distracting and easier to use while driving. This may explain why participants preferred pageswipe after using it while driving, even though they have indicated a preference for flickscroll before commencing the drive. It also highlights the importance of context when assessing suitability.

In a similar study undertaken by Kujala (2011), participants indicated a preference for page-by-page (referred to as 'buttons') while driving. Moreover, the flick scrolling technique ('kinetic') was least preferred by participants. This is likely to be influenced by the nature of the search task employed during the research. Kujala (2011) designed the search tasks and list configuration to be intentionally "demanding" and recognised "major complexity factors" in their research due to the absence of alphabetical ordering, the small font size used and the 3x4 grid layout of the menu items (Kujala and Saariluoma 2011). Furthermore, the items were presented using horizontal-scrolling, icon-based lists. Kujala (2011) therefore concluded that all the designs they used were "probably highly unsuitable for in-car use."

In contrast, the current study aimed to investigate use cases that were more representative of tasks that may currently be encountered when using touchscreens in vehicles. The font size used during the study was selected to be very close (given the limitations of the rendering software and screen resolution) to the suggested minimum font size for standard panel viewing distance (700 mm) based on the Bond Rule (Green et al. 1993). Furthermore, vertical word-lists closely resemble menus, and structuring allows users to anticipate where a target is located within the available options.

Although menus may not necessarily be ordered alphabetically, some form of structuring typically predominates, including, chronological, frequency and semantic. It is therefore suggested that the stimuli used during the current research were more representative of real-world scenarios and the results therefore benefit from greater ecological validity.

There was some evidence during the study that participants tended to make longer glances generally when viewing shorter lists, compared to medium and long lists. This may have been influenced by the nature of the search task itself and the relative contribution of non-search related glances. For instance, participants may have made longer glances at the start of each task in order to read and recognise the target word. Similar, longer glances may have been made at the end of each task to allow participants to guide their finger and select the word once revealed on screen. These longer glances have a greater relative impact on the mean glance duration for the short lists than for the medium or longer lists. It was also evident that all three techniques investigated during the study necessitated glances in excess of two seconds even for short lists. NHTSA investigated the impact of driver inattention on crash risk and highlight, in particular, off-road glances in excess of two seconds as a major contributor (NHTSA 2006).

Clearly, there are limitations and concerns with all three existing list-scrolling techniques investigated during the study. Overall, the results suggest that care should therefore be taken regarding the unsolicited transfer of interactive touchscreen technology from a sedentary to an automotive context. While driving, methods of interaction should be designed to minimise the visual and physical demand while using these devices. There is a temptation for UI designers to provide visual feedback that is aesthetically pleasing and engaging, yet this can clearly distract drivers and divert their attention away from the road situation. The results suggest that, in this aspect, there may be an advantage for page-swipe over rival methods for list-scrolling in vehicles but further research is required. If the adoption of touchscreen technology within cars is inevitable (as it appears so) further research should also investigate more novel interaction techniques that could reduce the visual demand associated with using the devices while driving. For example, it may be possible to identify generic, low visual-demand gestures to move through lists and interact with these devices more intuitively.

Conclusion

The study aimed to compare three different list scrolling techniques to move through one dimensional vertical word lists using an interactive touchscreen while driving. The techniques were taken from a non-automotive domain. The study therefore also sought to draw conclusions regarding their suitability for use within vehicles. The methods differed based on the target area of active UI elements (‘interaction area’) and the presentation of information (‘chunking technique’).

The page-by-page technique utilises a small interaction area but provides a regimented chunking technique. It therefore provides good control over list progression but is also the slowest technique to use while driving and demands the largest visual attention for long lists as users are required to locate a specific UI element to move through the list. In the study, page-by-page was associated with the largest impact on driving performance and was least preferred by drivers both before and after driving.

Using flickscroll and pageswipe allows drivers to move more quickly through longer lists. The techniques utilise a large, unbounded interaction area and therefore require little visual guidance to move through items. However, flickscroll naturally induces more variation and instability in the way that the list is displayed. Speed is therefore gained at the expense of accuracy and additional visual attention may be required to resume and fine-tune the search task. During the study, drivers preferred flickscroll before driving but felt that it was more distracting and difficult to use after they had used it while driving.

Pageswipe offers the benefits of both page-by-page and flick-scroll. It displays discrete ‘chunks’ of information and has a large interaction area. It is suspected that this may result in better task-resumability than flick-scroll and this would allow pageswipe to be more easily incorporated into the self-paced nature of driving. In the study, drivers preferred to use pageswipe while driving. However, further work is required to quantify the perceived benefits.

References

Cockburn, A., Gutwin, C. 2009. A Predictive Model of Human Performance With Scrolling and Hierarchical Lists, *Human-Computer Interaction*, 24: 3, 273–314

Collet, C., Guillot, A., Petit, C. 2010. Phoning while driving I: a review of epidemiological, psychological, behavioural and physiological studies. *Ergonomics*, 53(2010): 589–601

Crundall, D., Chapman, P., Trawley, S., Collins, L., Van Loon, E., Andrews, B., Underwood, G. 2012. Some hazards are more attractive than others: Drivers of varying experience respond differently to different types of hazard. *Accident Analysis & Prevention*, 45, 2: 600–609.

Green, P., Levison, W., Paelke, G., Serafin, C. 1993. *Suggested Human Factors Design Guidelines for Driver Information Systems*. Technical Report UMTRI-93-21

Hinman, R. 2012. *The Mobile Frontier*. Rosenfeld Media.

Kujala, T., Saariluoma, P. 2011. Effects of menu structure and touch screen scrolling method on the variability of in-vehicle glance durations during in-vehicle visual search tasks. *Ergonomics,* 54(8):716–732

Kujala, T. 2011 Browsing the information highway while driving: three in-vehicle touch screen scrolling methods and driver distraction.

Land, M. F., Horwood, J. 1995. Which parts of the road guide steering? *Nature* (Lond.) 377: 339-340

Lee, J.D., Regan, M.A., Young, K.L. 2008. What drives distraction? Distraction as a breakdown of multilevel control, in *Driver distraction: theory, effects, and mitigation, edited by* M. A. Regan, et al. CRC Press, Boca Raton: 41–56

Lee, J.D., Young, K.L., Regan, M.A. 2008. Defining driver distraction, in *Driver distraction: theory, effects, and mitigation, edited by* M. A. Regan, et al. CRC Press, Boca Raton: 31–40

Liang, Y., Lee, J. D. 2010. Combining cognitive and visual distraction: less than the sum of its parts. *Accident Analysis & Prevention*, 42, 3: 881-890.

NHTSA 2006. The Impact of Driver Inattention on Crash Risk: An Analysis using the 100-car Naturalistic Driving Study, National Highway Safety Administration, Report No. DOT HS 810 594

Ratwani, R.J., Andrews, A.E., McCurry, M., Trafton, J.G., Peterson, M.S. 2007. *Using peripheral processing and spatial memory to facilitate task resumption*. Presented at the Human factors and ergonomics society annual meeting, October 2007.

Regan, M.A., Lee, J.D., Young, K.L. (eds) 2008. *Driver distraction: theory, effects, and mitigation*. CRC Press, Boca Raton.