Proceedings of the First International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI 2009), Sep 21-22 2009, Essen, Germany

Assessing Subjective Response to Haptic Feedback in Automotive Touchscreens

Matthew J. Pitts Mark A. Williams Tom Wellings Alex Attridge
WMG, University of Warwick
Coventry
CV4 7AL, United Kingdom
+44 (0) 24 7657 5936
{m.pitts; m.a.williams.1; t.wellings; a.attridge}@warwick.ac.uk

ABSTRACT

The increasing use of touchscreen interfaces in vehicles poses challenges to designers in terms of optimizing safety, usability and affective response. It is thought that the application of haptic feedback to the touchscreen interface will help to improve the user experience in all of these areas. This paper describes the initial outcomes of a study to investigate user responses to haptic touchscreens using a simulated driving scenario based on the Lane Change Test, along with representative use case tasks. Results indicate preference for multi-modal feedback and user acceptance of the haptic feedback technology. Effects relating to multi-modal interaction and attentional demand are also observed.

Categories and Subject Descriptors

H.5 [Information Interfaces and Presentation]: User Interfaces - *Auditory (non-speech) feedback, Haptic I/O, Input devices and strategies (e.g., mouse, touchscreen), User-centered design*

General Terms

Experimentation, Human Factors

Keywords

Touchscreen, Haptic Feedback, HMI, Automotive

1. INTRODUCTION

The use of touch screen interfaces in both mobile devices and automotive technology is rapidly increasing [1] as more vehicle manufacturers adopt touchscreen-based HMI solutions for their latest vehicle line-ups [2][3]. Optimising usability and acceptance poses challenges to designers in both fields [4].

While touchscreens have usability benefits compared to centralised controllers as used by Audi and BMW for example [5], the interface places significant visual attention demand on the driver due to the lack of tactile and kinesthetic feedback [6]. Historical data shows that eye glances away from the road contribute to 60% of crashes, near-crashes and incidents [7]; re-introducing haptic feedback to provide confirmation of inputs may negate the requirement for secondary glances, thereby reducing the overall attention requirements of the touchscreen interface and improving both safety and the user experience.

There are potentially additional benefits in terms affective response to an interactive haptic interface. Research into the use of touch as an enhanced marketing tool found that touch created a enjoyable hedonic experience for the consumer [8]; given that preferences for feel characteristics in pushbutton vehicle interfaces are known to exist [9][10], user-selectable haptic effects would allow the user to personalise their experience to match their own tastes and requirements, thus enhancing their experience [11].

A study into haptic feedback in mobile devices with touchscreen interfaces [12] compared text entry tasks using a software keyboard with and without haptic feedback enabled. Results showed an improvement in error rates and reduced subjective workload with the addition of haptic feedback. In another study, haptic feedback was shown to reduce error rates and task completion time in a scrolling task on a handheld device [13]. Serafin et al [14] showed subjective preference for tri-modal (visual, audible and haptic) feedback from a touchscreen interface in on-bench and static vehicle trials; however, these trials were conducted in the absence of any external tasks requiring attentional resource.

2. EXPERIMENTAL APPROACH

A study was proposed to investigate the response of drivers towards touchscreens fitted with haptic feedback capability in an automotive scenario. The objective of the study was to ascertain the benefits of haptic feedback compared to existing modes of feedback commonly employed on in-vehicle systems, i.e. visual and audible feedback.

The research questions were as follows:

- Does touchscreen task performance improve with audible or haptic feedback?
- Do users show a subjective preference for audible or haptic feedback on touchscreens?
- Does the presence of audible or haptic feedback affect the demand level of touchscreen tasks?

AutomotiveUI'09, September 21-22, 2009, Essen, Germany
ACM 978-1-60558-571-0/09/009

- Is there a relative preference for either audible or haptic feedback?

The hypothesis was formed that the presence of haptic feedback would improve both objective and subjective measures of performance and affect.

As the objective of the study focused on in-vehicle touchscreen use, it was important to consider the context of the evaluation. In order to provide a degree of context and to introduce an element of cognitive workload, the evaluation tasks were conducted in a simulated driving environment based on the Lane Change Task software [15].

The driving task requires the user to change lanes on a straight road in response to signs positioned at the side of the road; as the signs are regularly spaced the driver is subject to a constant workload requirement. This approach also allows for collection of data on the performance of the lane change task (e.g. mean lane deviation) which may indicate differences between experimental conditions.

Figure 1 - Evaluation setup

The touchscreen evaluation tasks themselves were based on real-life use cases for an automotive application, described in section 2.3.2. The interface application was designed to log key presses and timings, allowing calculation of error rate and task completion time metrics to evaluate performance across experimental conditions; this approach has previously been used to illustrate benefits of haptic feedback on mobile devices [13].

In addition to the objective metrics described above, users were required to provide subjective measures of task performance and affect following each evaluation stage. This paper will concentrate on the collection and analysis of this subjective information, with further analysis of the objective data remaining as future work.

2.1 The Haptic Touchscreen Interface

The experiments were conducted using a Touchsense 8.4” LCD touchscreen demo unit from Immersion Corporation [16] – this device is supplied pre-fitted with haptic feedback actuators and control hardware and forms the visual and haptic display elements, as well as the touch input device. The graphical interface used for the trials was based on a production vehicle touchscreen GUI and was programmed in Adobe Flash CS3 and ActionScript 3.0. All interface functions were operated with ‘pushbutton’-type controls.

2.2 Pre-Trial Study

It was necessary to select one effect for use in the main trial in order to remove effect type as a variable and minimise negative affective responses. A pre-trial desk-top study to determine preference was conducted using 34 respondents from the automotive industry. Of these, 17 (50%) respondents described themselves as ‘experts’ in touchscreen interface design.

The Touchsense unit features a palette of pre-programmed haptic effects which can be called from software. These are grouped into five types: “Pulse Click”, “Crisp Click”, “Smooth Click” “Double Click”, and “Complex”. Effects within the ‘Click’ groups vary by magnitude and repeat rate, while the “Complex” effects exhibit much wider variations in both magnitude and character; these were therefore excluded from the evaluation. In order to reduce individual differences in touchscreen usage, all respondents were required to operate the screen with their left hand as per an in-car scenario (right-hand drive). Furthermore, respondents wore ear defenders during the evaluation to reduce cross-modal influence from the audible output of the haptic touchscreen actuators.

Respondents were presented with a series of screens, each having five buttons programmed with different feedback stimuli taken from one of the four ‘Click’ effect groups. The presentation order was randomised to reduce magnitude order effects. The respondent was asked to choose their most preferred ‘feel’ from the group of five, before moving onto the next screen where they were presented with effects from a different effect group. Once the respondent had chosen their preferred effect from each group, they were presented with a fifth screen comprising their previous preference selections and asked to make a final choice to determine overall preference.

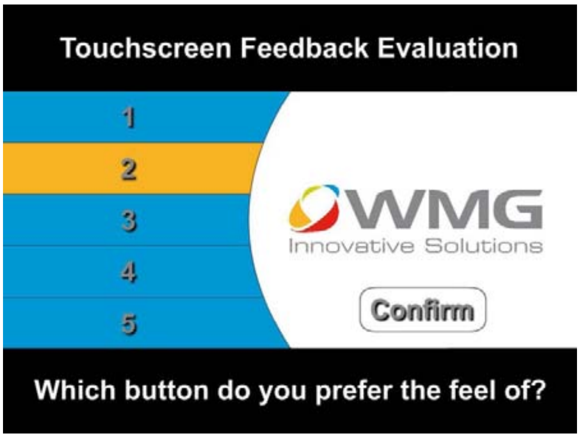

Figure 2 - Pre-trial interface screenshot

The pre-trial study also provided valuable insights into issues surrounding interaction with and implementation of the haptic touchscreen, including effect perceived quality and latency.

The results of the pre-trial indicated a preference for the “Crisp Click” effect type, with 16 of the 34 respondents selecting effects from this group as most preferred (see Figure 3). A binomial test of this result showed significance ($p<0.05$). There was no significant preference for one discrete effect, with three effects receiving similar scores. The effect used for the main study was chosen from these three after discussion within the research group.

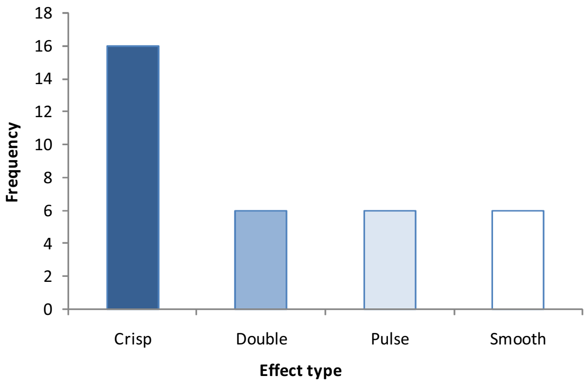

Figure 3 – Histogram of preferred haptic effect type

2.3 Main Study

2.3.1 Respondent selection

A total of 54 respondents participated in the study, with 48 completing the evaluation; six respondents were withdrawn from the study after either showing symptoms of simulator sickness or exhibiting poor driving performance. Selection criteria determined that all respondents were car drivers and had experience of in-car touchscreen use. The demographic breakdown is given in Table 1.

Table 1 - Respondent demographics

	Female		Male		Totals	
Age range	Count	% of Total	Count	% of Total	Count	% of Total
18-25	2	4%	3	6%	5	10%
26-35	4	8%	4	8%	8	17%
36-45	12	25%	5	10%	17	35%
46-55	2	4%	6	13%	8	17%
56+	1	2%	9	19%	10	21%
	21	44%	27	56%	48	100%

There was an exact 50%:50% split between users of portable touchscreen devices (such as handheld navigation units) and factory-installed touchscreen systems.

2.3.2 Experiment design

To test the hypothesis, respondents were presented with a series of use-case trials, based on operations which may be performed on an in-car touchscreen interface. Each set of trials was completed four times, once for each of the following combinations of feedback:

- Visual feedback only
- Visual + Audible feedback
- Visual + Haptic feedback
- Visual + Audible + Haptic feedback

One haptic feedback effect was used throughout the study to remove feedback type as a factor – this was a 'Crisp Click' type effect chosen based on the results of the pre-trail study. The audible stimulus was the acknowledgement 'beep' used on the touchscreen interface of a production premium saloon.

A screenshot of the evaluation interface is shown in Figure 4. As mentioned previously, the use cases were selected to encompass a range of functionality across the system, including climate control, audio system and telephone tasks, requiring different numbers of button presses and levels of menu navigation. These are summarised in Table 2.

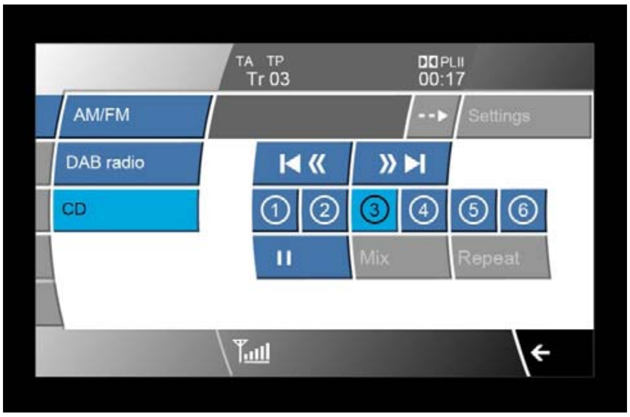

Figure 4 - Evaluation interface screenshot

For each of the feedback states, the use cases were modified where possible to reduce learning effects, for example by requesting a different DAB preset or fan speed setting. The order of presentation of use cases was predetermined, randomised between feedback states. The presentation of feedback states was counterbalanced for presentation order.

Table 2 - Use cases

Task	Button presses required	Menu levels
Set seat heating/cooling	3	0
Tune FM radio to given frequency	3	1
Select DAB station preset	3	2
Play track 4 from given CD	7	2
Set fan speed	4	1
Set climate control to auto/off	2	1
Dial phone number & start call	13	1
Select number from phone book	4	3

2.3.3 Training

A multi-stage training process was applied prior to the start of the evaluation in order to minimize learning effects. Firstly, respondents were shown a simple interface on the haptic touchscreen consisting of four buttons, each programmed to deliver a different combination of feedback stimuli, as shown in Figure 5. Audible signals were delivered over headphones which also provided acoustic isolation from the audible output of the haptic touchscreen actuators. For the purpose of simplicity, haptic feedback was referred to throughout the experiment as "Touch feedback". Respondents were asked to confirm that they could sense each stimulus, and that they understood the terminology used.

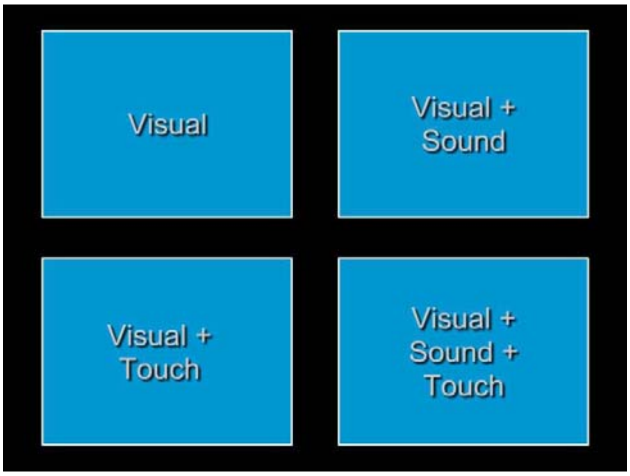

Figure 5 - Feedback introduction screen

Respondents were then introduced to the interface that would be used for the evaluations and instructed as to its functionality. After a period of familiarisation, the respondent was asked to demonstrate the completion of each of the use cases involved in the task.

Once familiar with the evaluation interface, the respondent was introduced to the driving task. The respondent was given instruction on the operation of the driving simulator, then asked to undertake a trial run. Additional instruction was provided for the initial part of the run until driving performance was deemed satisfactory. Due to the basic nature of the driving task the majority of respondents reached this status early in the trial run. The final stage of the learning process was to undertake a mock evaluation, whereby the respondent was required to operate the touchscreen while performing the driving task. Use cases were selected at random and instructions given verbally over the headphones.

2.3.4 Questionnaire design

Following each set of evaluations, respondents' subjective impressions were recorded using a questionnaire. Three types of rating scale were used [17]:

- 9-point hedonic rating scale - used to assess the overall liking for touchscreen use
- 9-point rating scale with verbal anchors at end and mid-points. This rating scale was used to assess usability elements of the task: confidence in choice, difficulty of operation while driving, interference with the driving task. For the trials including haptic feedback, additional questions were included on feedback realism (compared to real switch) and strength of the feedback stimulus
- 5-point Likert scale. This method was used to assess impressions of the technology concept across the different feedback states.

At the end of the evaluation, an additional questionnaire was presented. This consisted of two sections: in the first, respondents were asked to indicate their most and least preferred feedback combinations. The second section contained two questions aimed to assess the level of acceptance of haptic touchscreens, using a five-point Likert scale to measure the level of agreement with the statements: "Touch feedback makes the touchscreen more pleasurable to use"; and "Touch feedback makes the touchscreen easier to use"

3. Results

Of the 48 respondents who completed the study, five indicated in post-completion comments that they were not able to feel the haptic feedback stimulus; these respondents' data were therefore excluded from the analysis on the basis of their responses being unreliable. A further three respondents displayed extreme outliers in their responses and were also removed from the analysis.

Data from the remaining 40 participants was analysed to determine statistical significance across feedback types using the non-parametric Friedman's test. The paired Wilcoxon signed-ranks test with Bonferroni correction is used to determine post-hoc pair-wise significance at the 95% family-wise confidence level ($p_{crit} = 0.0085$).

A selection of findings from the analysis is shown below.

Figure 6 shows the mean hedonic rating for each feedback state. There is a clear trend for improved rating with multi-modal feedback which is shown to be significant ($p < 0.001$). The mean score of 6.00 for 'Visual only' feedback corresponds to the rating 'Like slightly' on the hedonic scale, while the mean value of 7.60 for the 'Visual + Audible + Haptic' state lies between the anchor points 'Like slightly' and 'Like very much'.

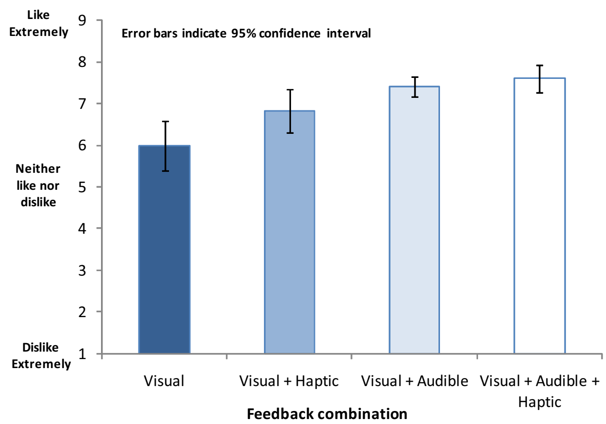

Figure 6 - Mean hedonic rating scores for each feedback combination. Sample size = 40

Post-hoc tests indicate that hedonic rating is improved from the 'Visual only' state with the addition of audible or combined audible and haptic feedback and that 'Visual + Audible' feedback shows an improvement over 'Visual + Haptic' (Table 3).

Table 3 - Mean scores, standard deviation and Wilcoxon Signed Rank pair-wise p-values for Q1: Hedonic Rating. Sample size = 40

Mean and Standard Deviation

	V	VH	VA	VAH
Mean	6.00	6.83	7.40	7.60
SD	1.91	1.66	0.78	1.08

Pair-wise p-values

	V	VH	VA	VAH
V	-	>0.05	**<0.0001**	**<0.0001**
VH		-	**0.0009**	0.0136
VA			-	>0.05
VAH				-

P_{crit} = 0.0085 (Family-wise $\alpha = 0.05$, 2-sided test)

Values in bold are significant

The trend across feedback types is repeated for confidence rating (Figure 7), with the 'Visual only' state attracting the lowest mean score and 'Visual + Audible + Haptic' the highest: a mean of 7.00, which lies between 'Moderately' and 'Extremely confident' on the rating scale. Differences across feedback states were shown to be significant ($p < 0.001$), with post-hoc tests showing improved confidence from the 'Visual only' state with the addition of audible or combined audible and haptic feedback, and improvement from the 'Visual + Haptic' state with the addition of audible feedback (Table 4).

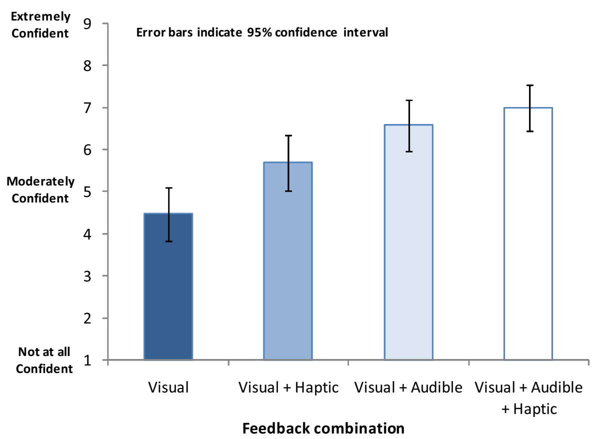

Figure 7 - Mean confidence rating scores for each feedback combination. Sample size = 40

Table 4 - Mean scores, standard deviation and Wilcoxon Signed Rank pair-wise p-values for Q2: Confidence in button press. Sample size = 40

Mean and Standard Deviation

	V	VH	VA	VAH
Mean	4.48	5.70	6.58	7.00
SD	2.06	2.14	1.95	1.80

Pair-wise p-values

	V	VH	VA	VAH
V	-	0.0099	**0.0002**	**<0.0001**
VH		-	>0.05	**0.0030**
VA			-	>0.05
VAH				-

P_{crit} = 0.0085 (Family-wise $\alpha = 0.05$, 2-sided test)

Values in bold are significant

Ratings of touchscreen task difficulty show a small but significant difference across feedback states ($p < 0.05$), with means ranging from 4.00 for 'Visual only' to 4.98 for 'Visual + Audible + Haptic' – an increase of only one scale point with the addition of multimodal feedback. Increases in standard deviation for multimodal feedback states suggest that some respondents found the touchscreen tasks consistently difficult and did not realise benefits from multimodal feedback. Post-hoc analysis showed significant differences for the 'Visual / Visual + Audible' and 'Visual / Visual + Audible + Haptic' pairs only. Rating scores for 'Interference with the driving task' follow the same pattern of mean scores and significant differences, with the highest mean rating of 4.40 for 'Visual + Audible + Haptic' indicating a 'more than moderate' level of interference.

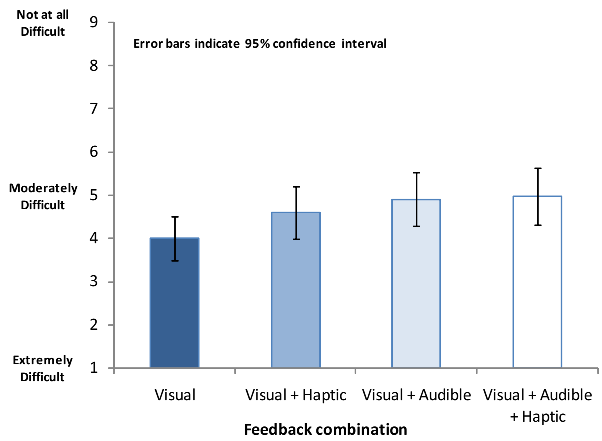

Figure 8 - Mean difficulty rating scores for each feedback combination. Sample size = 40

Table 5 - Mean scores, standard deviation and Wilcoxon Signed Rank pair-wise P-values for Q3: Difficulty in operating touchscreen while driving. Sample size = 40

Mean and Standard Deviation

	V	VH	VA	VAH
Mean	4.00	4.60	4.90	4.98
SD	1.63	1.96	2.00	2.13

Pair-wise p-values

	V	VH	VA	VAH
V	-	>0.05	**0.0044**	**0.0043**
VH		-	>0.05	>0.05
VA			-	>0.05
VAH				-

P_{crit} = 0.0085 (Family-wise $\alpha = 0.05$, 2-sided test)

Values in bold are significant

The reported strength of the haptic feedback stimulus also showed significant differences in mean rating with and without audible feedback ($p < 0.001$), indicating that the haptic effect was perceived as 'more strong' in the presence of audible feedback. This suggests a multi-modal effect whereby the presence of the audible feedback reinforces the perception of the haptic stimulus. The mean rating of 3.51 for 'Visual + Haptic' indicates that, on average, the strength of the haptic effect was less than optimal, as a score of 5 indicates 'Just right'. Note the smaller sample size of 35, due to this question being added part way into the study.

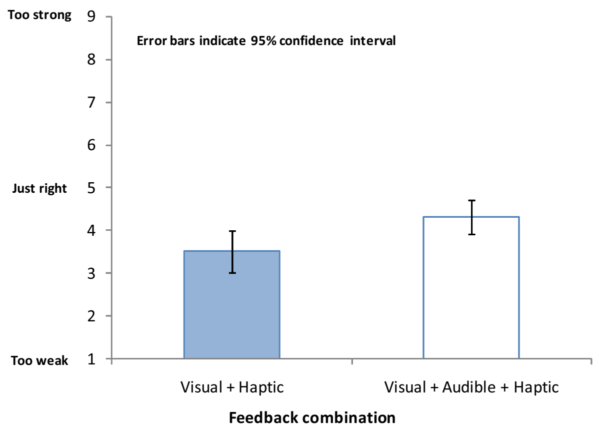

Figure 9 - Mean feedback strength rating scores for each feedback combination. Sample size = 35

While previous results do not indicate significant benefits for the addition of haptic feedback, alternative measures show user acceptance of the technology. Figure 10 shows the number of times each effect state was chosen as most or least preferred, with the least preferred choices shown as negative. A clear preference for combined visual, audible and haptic feedback can be seen, with 24 choices from 40 respondents – double that of the 'Visual + Audible' state; indicating that haptic feedback is seen as desirable by the user.

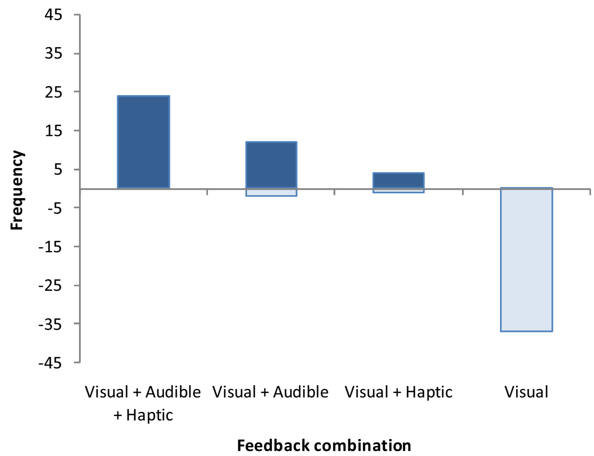

Figure 10 - Histogram of most/least preferred feedback state. Most preferred shown as positive, least preferred shown as negative. Sample size = 40

Further evidence for acceptance of haptic feedback is given by the responses to the questions 'Touch feedback makes the touchscreen more pleasurable to use' and 'Touch feedback makes the touchscreen easier to use'. The mean scores for these questions are 4.14 and 4.34, where a score of 4 corresponds to 'Agree' on the Likert scale.

3.1 Order effects

Results for questions relating to hedonic rating, touchscreen task difficulty and driving task interference were each analysed for differences due to the order of presentation of the feedback states using the Friedman's test ($\alpha = 0.05$). A significant order effect was found for driving task interference ($p < 0.001$), indicating that participants experienced less interference with the driving task when operating the touchscreen as the study progressed. Figure 11 shows the variation in mean interference rating with presentation order.

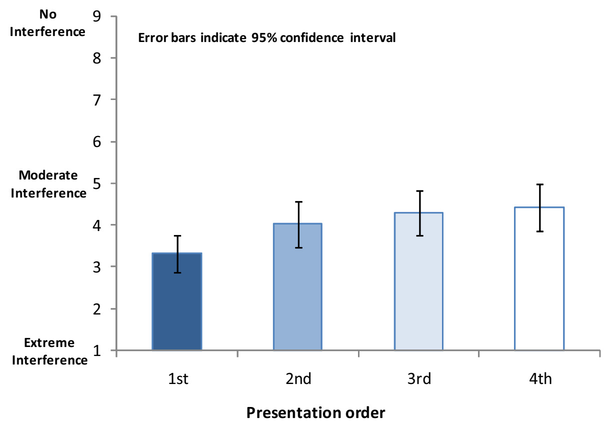

Figure 11 – Variation in mean interference rating with presentation order. Sample size = 40

4. Discussion

Hedonic ratings scores indicate a preference for tri-modal feedback, showing a trend across feedback states which is repeated for ratings of confidence. While combined visual, audible and haptic feedback attracts the highest mean scores, no significant differences are shown for the addition of haptic feedback to other feedback states. This concurs with the findings of Serafin et al [14], which indicated preference for "enhanced" (multi-modal) feedback.

Alternative measures were also used to assess users' affective response to haptic feedback. Combined visual, audible and haptic feedback was chosen as 'most preferred' by 24 of 40 respondents, double that of 'Visual + Audible'. This, along with results indicating that users 'agree' that haptic feedback makes the touchscreen both easier and more pleasurable to use indicate strong user acceptance of the technology. Kern et al [18] found that, while tactile feedback did not show benefits in driving performance, anecdotal evidence from participant comments suggested strong liking for combined audible and tactile feedback, citing advantage gained from reinforcement of perception of the signal when received simultaneously in two modalities.

Looking at the results for the 'Haptic feedback strength' question suggests that, when experienced without its audible counterpart, the haptic feedback stimulus was not sufficiently strong to provide a positive confirmation to the respondent. The haptic effect chosen was selected on the basis of a pre-study trial involving expert and non-expert users; one might assume that this process would reject effects that are 'Too weak'. Indeed, all respondents in the main trial confirmed that they could perceive the haptic feedback during the learning phase. However, a number of respondents also indicated that they had difficulty feeling the feedback during the evaluation tasks. The suggestion is therefore that simultaneous performance of the driving and touchscreen tasks imposes an attentional load which reduces the respondent's ability to perceive haptic stimuli – this agrees with by Leung et al [19], who observed similar differences in haptic sensitivity when participants were distracted.

Previous discussions with applications engineers have highlighted the potential for tuning haptic stimuli to account for background (vibration) noise in the vehicle environment, but the effect of attentional demand had not been discussed. The ability to tune effect magnitude would also compensate for individual differences in sensitivity to haptic stimuli, as well as allowing a user to tune the device to suit their personal preferences, thus maximising the affective benefits of a tactile interface discussed earlier.

The difference in rating for perceived haptic effect strength in the presence of the audible stimulus also suggests a multi-modal interaction effect. An interesting avenue of further study would be variations in perception of haptic effects with age; while vibrotactile sensitivity in the hand is known to decrease in older adults in a similar way to visual and auditory acuity [20], multi-modal stimuli have been shown to restore response times of older participants to those demonstrated by young subjects for single stimuli, suggesting that multi-modal feedback can compensate for age-related sensory degradation [21]. Unfortunately it was not possible to draw significant conclusions on age-related sensitivity effects from the study data.

Care was taken with to minimise effects of presentation order, through a counterbalanced experiment design and a multi-stage pre-trial training process. Analysis of order effects indicated that, while presentation order has no effect of hedonic rating or touchscreen task difficulty, there was a significant effect on interference with the driving task over the duration of the study, with the level of interference becoming lower as the study progressed. As the perceived difficulty of the touchscreen task was constant throughout (no significant order effect), it may be assumed that the perceived demands of concurrent performance of the touchscreen and driving tasks diminished as the study progressed. Additional training or practice time may have reduced this effect, although it may also be the case that the nature of the driving task was also a factor; the fact that the highest mean score achieved for the interference measure indicated a 'more than moderate' level of interference suggests that the demands of the combined tasks was relatively high.

A total of 8 respondents were rejected from the analysis due to unreliable responses. It is valid to question the effect that this may have on the balance of the experiment. Again, order effect analysis on the reduced data set showed no significant effect on hedonic or confidence rating, suggesting that removal of these data was not detrimental.

5. Conclusions

Results indicated a preference for multi-modal feedback over visual feedback only. Measures of hedonic rating and confidence did not show significant improvements with the addition of haptic feedback; however, the combination of visual, audible and haptic feedback consistently attracted the highest ratings – this combination was chosen as 'most preferred' by twice as many respondents as 'Visual + Audible'. Furthermore, respondents 'Agree' that haptic feedback makes the touchscreen interface both easier and more pleasurable to use. Differences in the perceived haptic effect strength with and without the addition of audible feedback indicate multi-modal interaction effects, while reported issues with sensitivity whilst engaged in the driving task suggest an effect on feedback perception caused by attentional load.

5.1 Further work

Analysis of the subjective data from this study has yielded some interesting results with respect to affective response to haptic touchscreen technology. Further insight will be gained from analysis of the objective data also gathered during the experiment, which will illustrate the relationship between task performance and affective response.

A follow-up study using an improved driving simulator environment is scheduled for summer 2009. This will allow the validation of existing experimental results and allow hypotheses bases on anecdotal findings of this research to be tested. Furthermore, this presents to opportunity to employ additional objective measures such as eyes-off-the-road time.

6. Acknowledgements

The authors would like to thank Dr. Carl Pickering and colleagues at Jaguar Land Rover Research for their technical support and input into this study. This research was funded by EPSRC and was conducted under the Warwick Innovative Manufacturing Research Centre (WIMRC) project "Designing the next generation of HMI for Future Intelligent Vehicles".

7. References

[1] "Touch-Screen Sales to Double by 2012". http://www.cellular-news.com/story/24451.php. 20th June 2007, Accessed 29th May 2009.

[2] Jurnecka, R.: "All Volkswagens built after 2008 to get touchscreen system". http://blogs.motortrend.com/6220413/car-news/all-volkswagens-built-after-2008-to-get-touchscreen-system/index.html, November 12th 2007, accessed 19/01/09

[3] Newcomb, D.: "The Touch Screen Is Dead (In Acuras), Long Live the Touch Screen (In Other Makes)". http://blogs.edmunds.com/strategies/2008/12/thetouch-screen-is-dead-in-acuras-long-live-the-touch-screen-in-other-makes.html. December 16th 2008, accessed 19/01/09

[4] "Consumers warm to the touch screen phone" Canalys research release 2007/061. http://www.canalys.com/pr/2007/r2007061.pdf; Accessed 29th May 2009

[5] Rydstrom, A., Bengtsson, P.,Grane, C., Brostrom, R., Agardh, J, Nilsson, J.: "Multifunctional Systems in Vehicles: A Usability Evaluation". Proc. CybErg 2005.

[6] Burnett, G.E., Porter, J.M.: "Ubiquitous computing within cars: designing controls for non-visual use" International Journal of Human-Computer Studies, 55. 2001. pg 521-531

[7] Klauer, S.G., Dingus, T. A., Neale, V. L., Sudweeks, J.D., Ramsey, D.J.: "The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data". National Highway Traffic Safety Administration Report DOT HS 810 594. April 2006. Pg 99-109

[8] Peck, J., Wiggins, J.: "It Just Feels Good: Customers' Affective Response to Touch and Its Influence on Persuasion" Journal of Marketing Volume 70, Issue 4. October 2006, Pg56-69

[9] Wellings, T., Williams, M., Pitts, M: "Customer perception of switch-feel in luxury sports utility vehicles", Food Quality and Preference, Volume 19, Issue 8, December 2008, Pg 737-746.

[10] Wellings, T., Williams, Tennant, C: "Understanding customers' holistic perception of switches in automotive human-machine interfaces", Applied Ergonomics, In Press, Available online 17 April 2009, DOI:10.1016/j.apergo.2009.03.004.

[11] MacLean, K.E.: "Designing with haptic feedback". Proceedings ICRA '00: IEEE International Conference on Robotics and Automation, 2000. pg.783-788.

[12] Brewster, S., Chohan, F., Brown, L.: "Tactile Feedback for Mobile Interactions". Proceedings of the SIGCHI conference on Human factors in computing systems, 2007. Pg 159 – 162.

[13] Poupyrev, I., Maruyama, S., Jun, R.: "Ambient Touch: Designing Tactile Interfaces for Handheld Devices". CHI Letters 4 (2), 2002, pg 51-60

[14] Serafin, C., Heers, R., Tschirhart, M., Ullrich, C., Ramstein, C.: "User Experience in the U.S. and Germany of In-Vehicle Touch Screens with Integrated Haptic and Auditory Feedback". SAE world congress 2007, 2007-01-0451

[15] Mattes, S.: "The Lane-Change-Task as a Tool for Driver Distraction Evaluation". In: Strasser, H., Kluth, K., Rausch, H., Bubb, H. (eds.) Quality of Work and Products in Enterprises of the Future, 2003 pg. 57–60.

[16] Touchscreen Feedback Overview, Immersion Corporation. http://www.immersion.com/products/touchscreen-feedback/index.html. Accessed 1st June 2009

[17] Stone, H., Sidel, J. L. (eds): "Sensory Evaluation Practices" (Third Edition) 2004. Pg 79-139

[18] Kern, D., Marshall, P., Hornecker, E., Rodgers, Y., Schmidt, A.: "Enhancing Navigation Information with Tactile Output Embedded into the Steering Wheel". Proceedings of the Seventh International Conference on Pervasive Computing, 2009

[19] Leung, R., MacLean, K., Bertrlsen, M.B., Saubashik, M.: "Evaluation of Haptically Augmented Touchscreen GUI Elements Under Cognitive Load". Proceedings of the 9th international conference on Multimodal interfaces, 2007, pg 374-381

[20] Jones, L.A., Lederman, S.J.: "Human Hand Function", Oxford University Press US, 2006. Pg 152-155

[21] Laurienti, P.J., Burdette, J.H., Maldjian, J.A., Wallace, M.T.: "Enhanced multisensory integration in older adults" Neurobiology of Aging, Volume 27, Issue 8, August 2006, Pg 1155-1163