Drivers' quality ratings for switches in cars: Assessing the role of the vision, hearing and touch senses

Gary Burnett
Human Factors Research Group
University of Nottingham
Nottingham, UK.
NG7 2RD
+44 (0)115 9514030
gary.burnett@nottingham.ac.uk

Ainojie Irune
Mixed Reality Lab (MRL)
School of Computer Science
University of Nottingham, UK.
NG8 1BB
+44 (0)115 9514226
aai@cs.nott.ac.uk

ABSTRACT
Sensory integration is critical to the perception of quality in automobile interior design. To investigate the relative contribution of the senses of vision, touch and hearing to the perception of quality for in-car switches, 30 participants rated eight switches taken from two vehicles when all senses were available and under various conditions of sensory deprivation: no hearing; no vision; no touch. Results indicated that touch had the greatest role to play in judgements of quality, enabling participants more easily to differentiate between the two vehicle designs. Furthermore, correlation and regression analyses for specific switches indicated that touch contributed up to three times as much to quality ratings compared to either the vision or hearing senses. Future research should aim to verify such findings and to establish which aspects of touch have particular influence.

Categories and Subject Descriptors
H.5.1 [Multimedia Information Systems]: Evaluation, Methodology; H.5.2 [Information interfaces and presentation]: User Interfaces, User-centered design, Interaction styles, Haptic I/O

General Terms
Design; Human Factors

Keywords
Quality perception; In-car switches; Affective design; Usability

1. INTRODUCTION
Designing consumer products to account for a human's affective needs is now widely recognised to be an important and growing research area within Human Factors and Human-Computer Interaction (HCI). As is commonly the case for emerging topics (particularly those which are interdisciplinary), a variety of overlapping terms exist in the literature as labels for the concept, including: affective human factors design [8]; emotional design [12]; hedonomics [4]; engineering aesthetics [11]; hedonic quality [3]; pleasure-based design [7]; and emotional usability [9].

The prevailing view relevant to all terms is that designers should consider a broader perspective of the user-product experience, given that products are increasingly associated with users' lifestyles. In particular, it is noted that official definitions of usability [5], with their emphasis on task completion measures, do not account for the full scope of human-focused qualities that a product must possess to be successful in the marketplace [7].

Such a shift in emphasis takes Human Factors and HCI into the domains traditionally considered by those working in marketing and consumer behaviour, in particular, the area of quality perception. In assessing the quality of a product, such as an automobile, users typically assimilate and synthesise information from across the senses. For cars, a common scenario in which critical quality ratings are made concerns the 'show room' experience, specifically, encounters made with the vehicle interior including interactions with the range of switches on offer. Ultimately, this multi-sensory 'contact' with a product, and the subsequent quality judgements made, will have a significant effect on overall purchasing decisions [6, 16]. For vehicles, such interactions are of particular importance given the rapid rise in the adoption of new technologies (e.g. satellite navigation) with their potentially complex user-interfaces [1].

As researchers trying to understand this situation scientifically, it is clear that a wide range of factors (relating to switch design, and task, individual and environmental issues) will have an impact on overall ratings of quality for switches in a car. Figure 1 attempts to highlight this complexity, by providing a non-exhaustive listing of factors expected to contribute to quality perception according to different categories.

Whilst useful in developing an appreciation of the problem, such an analysis provides little assistance for vehicle manufacturers attempting to design switches to maximise quality ratings. Moreover, it is clear that there are too many variables to be sensibly considered in an experimental research programme. Accordingly, there is a need to generate knowledge which enables switch designers to restrict the design space associated with this problem, that is, to focus on the specific design characteristics in further work/development which are most likely to impact on quality ratings. An understanding of the comparative role of the three key senses of vision, hearing and touch to the perception of in-car switch quality would provide such information. Designers would then be able to concentrate their efforts on the limited range of design factors relevant within specific senses.

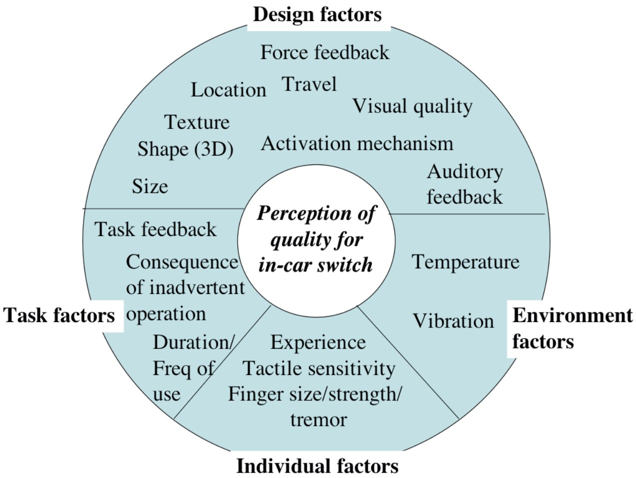


Figure 1. Range of factors relevant to perception of in-car switch quality

The aim of the present study was to establish the relative contribution of the three primary senses (vision, touch and hearing) to the perception of quality for in-car switches. In searching the literature prior to the start of the study, it was clear that there was no research reported that considered this specific issue. Therefore, the design of the study drew initially on the model of the quality perception process proposed by Steenkamp [15] where it is argued that quality perception is primarily affected by five key variables:

1. Quality cues – either physical characteristics of the product (intrinsic) such as its shape, size, and so on, or features associated with the product (extrinsic) such as its brand name, pricing, etc.
2. Quality attributes – perceived benefits of the product, such as the functions and potential social advantages it offers, either based on actual experience or expert viewpoints.
3. Interactions – the context in which the human engages with the product prior to making quality ratings, including the physical and social environment, and whether it is possible to make comparative judgements.
4. Timing – whether ratings are made pre or post consumption, that is, before or after extensive use of the product.
5. Personal perspective – individual differences, such as level of education, product knowledge, motivation, and so on.

In considering the 'show room' scenario, it is clear that quality perception in this situation is largely pre-consumption and involves static consumer-vehicle interactions with non-operational switches, often in a comparative fashion. Furthermore, both quality attributes and quality cues (intrinsic and extrinsic) are utilised in making judgements. In developing a study methodology which could investigate the relative contribution of the senses to quality perception in a design context, it was clear that intrinsic quality cues were of greatest relevance. Moreover, extrinsic quality cues (particularly branding) were likely to confound any results relevant to intrinsic cues. Therefore, a critical aspect of the methodology concerned the exclusion of extrinsic quality cues.

A further consideration in the design of the study was whether to take a survey or experimental based approach. Within the marketing domain, researchers have conducted large-scale surveys in order to ascertain the relative impact of the senses in the development of brand loyalty [10]. However, whilst the use of surveys may be appropriate when considering consumers' opinions for generic qualities such as brand image, they are not suitable as a method for investigating users' direct sensory experience with a product. Consequently, an experiment was conceived in which participants' multi-sensory encounters with in-car switches were manipulated in a systematic fashion. In this regard, it was anticipated that the presence (or conversely, the absence) of a sense would provide information regarding its relative contribution to quality perception.

2. METHOD

2.1 Participants

Thirty participants took part in the study (18 male and 12 female); the majority were aged between 18 and 35. Participants were generally experienced and regular drivers – on average, they had possessed a full UK driving licence for 11 years (SD=7.00, Range 3-30) and drove 4.3 days per week (SD=2.45, Range 2-7). None of the participants had experience with either of the two cars associated with the study.

2.2 Equipment

Two control panels were constructed for the study (Panel 1 and Panel 2) – see Figure 2. Each contained an array of switches taken from the central dashboard and driver door areas of a commercially available 'medium' (C) class car. The two arrays were chosen because it was felt they, a) represented typical examples of current switch design, and b) they provided a range of switch designs with varying sensory qualities. The panels were built to be solid (so that they did not move when switches were pressed) and portable (so that they could easily be moved to alter the presentation to the left/right of the participant). Furthermore, the panels were anonymised (i.e. by placing stickers over company names/logos) so that participants could not readily associate them with specific manufacturers. The switches were non-operational, that is, operating them did not lead to the execution of a function, such as turning the audio system on.

2.3 Experimental Design

In a repeated measures design, all 30 participants pressed a range of switches from both of the panels under each of the following conditions:

A. NO HEARING, i.e. touch and vision only. In this condition, whilst interacting with the panels, participants wore headphones through which classical music was played at a constant volume.

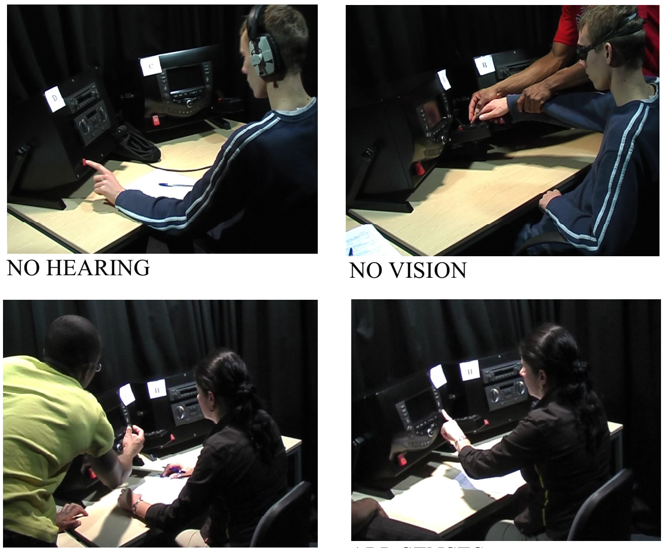
B. NO VISION, i.e. touch and hearing only. Participants wore a blindfold comprising blacked out goggles.

C. NO TOUCH, i.e. vision and hearing only. In this case, the switches were operated by the experimenter, whilst the participant watched and listened.

D. ALL SENSES, i.e. touch, vision and hearing.

Figure 2. Panels 1 and 2 (with examples of labelling used)

Participants experienced each of the restricted sense conditions in a counterbalanced order (i.e. five did A-B-C, five A-C-B, five B-A-C, and so on). All participants experienced the 'ALL SENSES' condition at the end of the experiment, that is, as the final condition. Figure 3 highlights the four conditions experienced in the study.



NO HEARING NO VISION

NO TOUCH ALL SENSES

Figure 3. Conditions used in the study

2.4 Tasks

For each panel, the following eight tasks (and their associated switches) were used: hazard on/off; audio on/off; increase/decrease audio volume; seek up/down radio station; eject CD; demist the rear window; recirculate the air within the car; and raise/lower driver window. The tasks were chosen for two primary reasons: they were all common in-car secondary tasks; and the switches needed to execute the tasks were associated with a range of visual, auditory and touch characteristics.

2.5 Dependent variables

The two principal dependent variables captured in the study were quality ratings and preferences, for both individual switches and panels as a whole. Quality ratings were made using a simple five-point numerical scale with semantic anchors (very poor quality; very high quality) in which the following question was set: What sense of quality does using this switch/panel provide? In addition, participants were encouraged to speak aloud during the study and sessions were videoed in order to provide qualitative supporting data regarding drivers' opinions.

2.6 Procedure

Initially, participants completed a consent form and a questionnaire regarding their driving experience. They were then provided with an overview of the study's aims and informed in general terms of what would occur during the course of the study.

In planning the study, it was felt that participants might develop an overall view of a panel based on their initial experiences which would affect subsequent ratings. To counteract this possibility, participants were led to believe that eight panels were being rated. This was achieved by:

- Informing participants at the beginning of the study that there were eight panels to be rated, stressing that whilst they would look similar, they might differ with respect to a range of visual, sound and/or touch characteristics.
- Keeping panels hidden behind curtains until the experimenter was ready to commence a condition. During this time an assistant moved the panels around as if different panels were being introduced.
- Placing different labels onto the panels (letters A to H).

For each condition, participants were presented with the panels in pairs on a desk in front of them. For each of the eight tasks described in section 2.4 (taken in turn in a fixed order), the switches for both panels were then operated using the appropriate hand/finger for a right-hand drive vehicle (i.e. left hand and index finger for all switches apart from the driver door control). For all conditions (apart from the 'NO TOUCH' condition), participants were instructed to operate the switches 'a few times'. In the 'NO TOUCH' condition, the experimenter operated the switches (typically, two to three times) according to the participants' instructions. In the 'NO VISION' condition, participants' hands were guided towards the switches. Following an interaction with the two switches for a given task, participants were instructed to make a quality rating for the individual switch for each of the panels and to state an overall preference.

When all the eight tasks had been covered within a condition, participants rated the quality of both panels as a whole and gave a panel preference. The experimenter then moved onto the next condition. The study lasted approximately one hour in total.

3. RESULTS

3.1 Overall panel preferences and ratings

Figure 4 reports the number of participants who gave an overall preference for each of the two panels according to each of the four experimental conditions. The graph shows clearly that there was a significant preference for panel 1 over panel 2 throughout the study, apart from the 'NO TOUCH' condition where there was a marginal preference for panel 1.

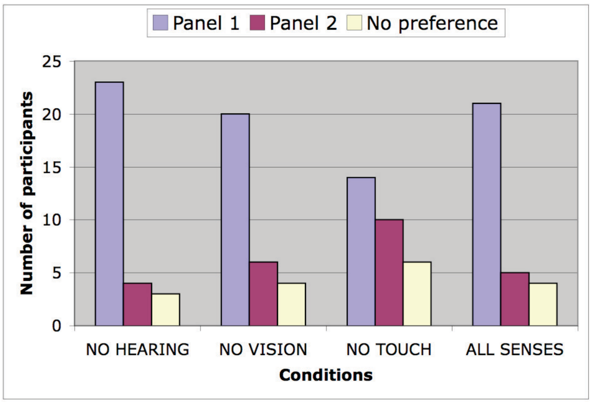


Figure 4. Responses to question, 'Which panel did you prefer for quality?'

Table 1 shows the ratings (means with standard deviations in brackets) for the two panels according to each of the four experimental conditions. The table highlights the fact that panel 1 was generally rated to be of higher quality than panel 2 for all conditions, apart from the 'NO TOUCH' condition in which there were no apparent differences in ratings. Two-tailed paired t-tests confirmed such an observation.

Table 1. Responses to question 'What sense of quality did the panel provide?' – means, standard deviations (in brackets) and p-values: where 1=Very Poor Quality; and 5=Very High Quality

Condition	Panel 1	Panel 2	Paired t-test
NO HEARING (n=30)	3.5 (0.860)	2.8 (0.711)	$p<0.005$
NO VISION (n=30)	3.5 (0.682)	2.6 (0.809)	$p<0.0005$
NO TOUCH (n=30)	3.2 (0.785)	3.1 (0.860)	$p=0.27$
ALL SENSES (n=30)	3.6 (0.621)	2.8 (0.714)	$p<0.0001$

A bivariate correlation analysis was then conducted in which the presence or absence of a sense was indicated in a spreadsheet utilising '1' or '0' respectively. Table 2 shows the Pearson correlations between the presence/absence of each of the senses and the ratings for each of panels as a whole. The table reveals that the presence of touch was significantly related to ratings for panel 1, whereas the absence of touch was significantly related to ratings for panel 2.

Table 2. Pearson correlations between absence/presence of touch and quality ratings for panels

Sense	Panel 1	Panel 2
Touch	0.16*	-0.21*
Vision	-0.02	0.16
Hearing	-0.05	0.01

* $p<0.05$ (two-tailed)

3.2 Individual switch preferences and ratings

With respect to the preference data for individual switches, Table 3 provides a summary of the results showing the switches where:

- There was a strong preference for a switch from panel 1 over the equivalent switch from panel 2, defined as occurring when at least two thirds of participants (20 from 30) indicated that they preferred panel 1
- There was a strong preference for a switch from panel 2 over the equivalent switch from panel 1, occurring when at least two thirds of participants preferred panel 2
- There were no strong preferences for a switch from either of the two panels, that is, when neither of the above criteria could be applied

Table 3. Responses to question 'Which switch did you prefer for quality?' – listing of switches

Condition	Panel 1 strongly preferred c.f. Panel 2	Panel 1 switch similar prefs c.f. panel 2	Panel 2 strongly preferred c.f. Panel 1
NO HEARING	Hazard, Window, Seek, Audio on/off, Eject CD, Recirculate	Volume, Demist	
NO VISION	Hazard, Window, Seek, Eject CD, Recirculate	Audio on/off, Volume, Demist	
NO TOUCH	Hazard, Window, Seek	Audio on/off, Volume	Recirculate, Demist, Eject CD
ALL SENSES	Hazard, Window, Seek, Eject CD, Recirculate, Volume	Audio on/off, Demist	

A similar analysis was conducted for the rating data utilising two-tailed paired t-tests and the results are shown in table 4.

Table 4. Responses to question 'What sense of quality did the switch provide?' – listing of switches

Condition	Panel 1 switch rated > than Panel 2 switch*	Panel 1 switch rated the same as Panel 2 switch	Panel 2 switch rated > than Panel 1 switch*
NO HEARING	Hazard, Window, Seek, Eject CD, Recirculate	Audio on/off, Volume, Demist	
NO VISION	Hazard, Window, Seek, Eject CD, Recirculate	Audio on/off, Volume, Demist	
NO TOUCH	Hazard, Window, Seek	Audio on/off, Volume, Recirculate, Eject CD	Demist
ALL SENSES	Hazard, Window, Seek, Eject CD, Recirculate, Volume	Audio on/off, Demist	

* $p<0.05$ (two-tailed)

A bivariate correlation analysis was conducted to assess the relationship between the presence/absence of each of the three senses and quality ratings for each of the individual switches (from both panels). Table 5 shows the results of this analysis for those switches where at least one significant correlation occurred (according to a two-tailed test).

Table 5. Pearson correlations between absence/presence of touch and quality ratings for key switches

	Panel 1		Panel 2		
Sense	Eject CD	Re-circulate	Seek	Eject CD	Demist
Touch	0.32**	0.17*	-0.35**	-0.33**	-0.19*
Vision	0.05	0.02	0.15	0.24**	0.16
Hearing	-0.22*	-0.07	0.10	0.05	0.08

* $p<0.05$ (two-tailed); ** $p<0.01$ (two-tailed)

As the "Eject CD" switch was associated with significant correlations for at least two of the senses, it was decided to conduct a linear multiple regression analysis for this switch to assess the relative contribution of the different senses to overall ratings. This revealed that the three senses accounted for a significant amount of the variance in quality ratings for the "Eject CD" switch for both panel 1: $F(3, 116)=5.69$, $p<0.001$ and for panel 2: $F(3,116)=5.66$, $p<0.001$. In both cases, the senses accounted for 13% of the variance in ratings. With respect to the specific contribution of each sense, touch was the only sense in which the contribution was significant, and table 6 shows the standardised coefficients for each of the senses for the "Eject CD" switch for each panel.

Table 6. Standardised coefficients (Beta) for each sense for Eject CD switch for each panel

	Panel 1		Panel 2	
Sense	Beta	Sig level	Beta	Sig level
Touch	0.34	p<0.005	-0.27	<0.05
Vision	0.11	p=0.19	0.16	p=0.14
Hearing	-0.06	p=0.56	0.01	p=0.89

3.3 Order analysis

During the informal scanning of the data, it was clear that an order effect existed in the results, focused specifically on the 'NO VISION' condition. A more detailed analysis revealed that preferences and ratings for the 'NO VISION' condition were significantly different dependent on whether this condition was experienced first or as the second/third condition. Figure 5 and Table 7 summarise this finding.

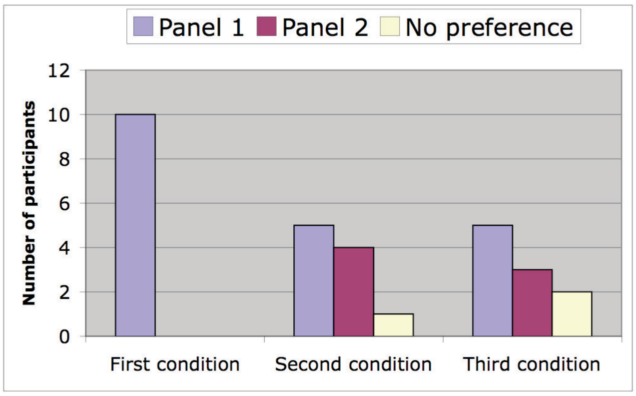


Figure 5. Responses to question 'Which Panel did you prefer for quality?'- NO VISION condition only, split by order

Table 7. Responses to question 'what sense of quality did the panel provide?' NO VISION condition only, split by order – means, standard deviations (in brackets) and p-values: where 1=very poor quality; and 5=very high quality

Condition	Panel 1	Panel 2	Paired t-test
1st condition (n=10)	3.8 (0.421)	1.8 (0.632)	P=0
2nd condition (n=10)	3.3 (0.622)	3.0 (0.632)	P=0.08
3rd condition (n=10)	3.5 (0.926)	3.1 (0.333)	No difference

4. DISCUSSION

4.1 Which sense provides the greatest contribution?

Taking the results as a whole, it is argued that touch provides the greatest contribution to drivers' ratings of switch quality in a static situation. Indirect evidence is apparent from participants' preferences and ratings of each of the two panels, which were similar for all conditions, apart from the situation in which participants were deprived of the ability to use their sense of touch. When touch was removed, participants did not generally differentiate between the panels with respect to the quality of the switches. This is despite the fact that switches from the two panels differed considerably in relation to their visual (e.g. size, shape) and auditory (e.g. amplitude/frequency of feedback sounds) characteristics.

More direct evidence was established from the correlation analyses where the factor of touch had a significant positive relationship with quality ratings for panel 1, and a significant negative relationship with ratings for panel 2. In other words, the touch-related characteristics of panel 1 led to increased ratings of quality, whereas the opposite was true for panel 2. No such relationship was observed for the other senses. More detailed assessments for individual switches found that specific switches were associated with a strong touch 'sensitivity', that is, touch has a considerable positive or negative relationship with quality ratings. For instance, according to a regression analysis conducted for the "Eject CD" switch, the sense of touch provided approximately three times as great a contribution to ratings, as compared with the other senses.

Final support for the significance of touch was revealed in an unexpected order effect. Those participants who experienced the panels first without vision were noticeably more differentiating in their preferences and ratings for this condition, as compared to those who had seen the panels earlier in the experiment. With a 'blind' initial experience, it is argued that participants were acutely sensitive to differences in the touch-related characteristics of the switches (also noted by Burnett and Porter [1]). In contrast, when the non-vision condition occurred at a later stage, a visual mental model of the panels might have already been developed, which was used in subsequent quality judgements.

4.2 Why is touch so important?

Returning to Steenkamp's model of the quality perception process [15] it was apparent that perhaps the most significant reason for the importance of touch concerns the nature of the human-switch interaction. Touch is evidently the only sense from the three investigated in this study which necessitates a 'close' physical interaction, that is, the human must be near to the object (in this case a switch) in order to use the sense. Burnett and Porter [1] have made this point in stressing the need for utilising a greater range of touch and kinaesthetic cues in in-car control design, in particular as a means of enabling drivers access to new technology systems (e.g. navigation, email, Internet services). In making the argument, Burnett and Porter cite research from the Virtual Reality domain in which haptic interfaces have been shown to increase users' sense of emotional involvement in collaborative tasks, in relation to traditional visual and auditory interfaces [14].

Furthermore, it was evident in many of the comments made by participants during the study that the intrinsic quality cues associated with the sense of touch were fundamental to drivers' ratings of in-car switches. Interestingly, in making a quality judgement some participants were clearly using intrinsic touch-related cues, but were also concerned with absent extrinsic quality cues, notably regarding pricing. The following comments provided by two participants highlight the importance of intrinsic touch cues as well as the significance of extrinsic quality cues for an image-related product such as an automobile [15].

> "This one [Panel 2] felt cheaper to me. Some of the buttons seem like they would end up breaking after not too long"

> "[The two panels] are quite similar in different things, but there are a couple of buttons which really deteriorate the whole thing [for Panel 2]. So, for example the Seek button here feels very cheap… very cheap and very tacky"

Further issues concerned the context in which the ratings were being made. Despite the fact that ratings were being made in a static situation, some participants considered the importance of touch when using in-car switches whilst driving. As commented by one participant:

> "Once I know my radio I want to be able to do it with no visual input at all, just feel the thing. So, I suppose… size of buttons will be a lot more important. I don't normally stare right at my radio… unless I'm stationary obviously. Most of the time I'm… fiddling around hoping I'm pressing the right button"

The findings in relation to specific switches are also of interest, as they highlight key influences for the overall panel results. The preferences and ratings for switches associated with three functions ("Demist", "Recirculate" and "Eject CD") were largely the same for all conditions, apart from the situation in which touch cues were absent. Without touch, participants' views altered from a general preference for panel 1 to a preference for panel 2. It was unsurprising that these three switches were associated with similar trends in the data as they had comparable designs (within a panel). Nevertheless, across the two panels there were considerable differences between the three switches, in particular in relation to their touch characteristics (e.g. the surface texture, force/travel relationships). In relation to the participants' experiences, the three switches for panel 1 had what was commonly referred to as a 'soft' feel, whereas the switches for panel 2 were often referred to as 'clicky' or 'harsh'.

4.3 What future work is required?

The significance of touch in the judgement of the quality of in-car switches raises the question: Which characteristics of touch are most important? In addressing this question, it must first be noted that a number of design characteristics will be of relevance, for instance, force feedback and travel distributions, switch lateral stability, texture, size, shape, and so on. Related work within vehicles has taken a Kansei Engineering approach in order to identify variables considered to be of relevance to the perception of quality for the touch factor, either of seat fabrics [2], or of surface materials on components such as the steering wheel [16]. Clearly, research is required which focuses on the relative priority of touch characteristics for in-car switch panels.

A further key issue concerns individual differences in the perception of quality for in-car switches. Whilst the results of this study indicate that touch had the greatest role across participants, it was apparent from the spread of data that this was not a universal truth. In this respect, research in the marketing area is of particular interest. Peck and Childers [13] have developed a questionnaire which aims to establish the 'need for touch', that is, the extent to which people require touch-related information when interacting with a potential product. Evidently, there is a need to understand how consumers with varying 'need for touch' preferences are likely to respond to in-car switch designs with differing degrees of tactile features.

Whilst important as an initial study in this area, it must also be recognised that a range of limitations exist in the present study. Consequently, there is a requirement to verify results. Three key considerations for future work include:

1. The need for a wider range of switch characteristics. A concern with this study is that the results are unique to the panels and tasks utilised.
2. The need to utilise switches fitted in representative locations within a vehicle. Whilst the use of panels enabled easy experimental manipulation, it was not possible to arrange them in the same orientations in which they would be operated in a vehicle.
3. The need to consider the relationship between the consistency of switch characteristics and the effect on subsequent ratings. That is, do ratings for an overall design improve or reduce if switches look, feel and/or sound the same? In this study, consistency of switch design was not manipulated as an independent variable, yet it was evident from some participants' comments that it had an influence on ratings.
4. The need to consider the specific influences of the driving task on the perception of quality for in-car switches. Whilst this paper has argued the importance of the initial showroom experience for vehicle purchases, comments made by participants highlight the impact that driving conditions will have ultimately on quality perception (e.g. due to varying vibration, noise, illumination).

5. CONCLUSIONS

On the basis of the results described in this paper, it is argued that the most important sense to get right in designing in-car switches is touch. If the touch-related characteristics of the switches of a vehicle are positively received, this can significantly enhance quality ratings. Perhaps more importantly, if the touch aspects of switches are viewed in a negative light, quality ratings can be considerably reduced. Moreover, quality ratings for an overall design can be strongly affected by the judgements made on specific switches - particularly those with well or poorly regarded touch characteristics.

Touch is considered to be of particular significance in this context for two key reasons. Firstly, there is an intimacy in the use of touch which is congruent with the nature of making a subjective quality rating. Secondly, touch-related feedback can be critical in the visually demanding driving situation, a fact which consciously or subconsciously affects drivers' views on the quality of in-car switches.

It is worth noting that the results of this study are of particular significance given the recent trend for the use of touchscreen technology within vehicles. Traditional touchscreens provide minimal touch cues to users (only the feedback of pressing against a solid object) and instead place an emphasis on visual and auditory information during interaction. The results of the present study suggest that such devices fail to provide cues to drivers that would be considered important in this context. Haptic touchscreens now exist though (see [17]) and it would be of interest to examine their use in a vehicle environment. Such research could investigate the design variables that influence quality perception with such technology. Moreover, it would be extremely worthwhile to consider whether haptic touchscreens reduce visual distraction in relation to traditional touchscreens.

As a final point, it is also important to note that vision and hearing clearly also impact on quality ratings for in-car switches and should not be ignored in the design process. Whilst it is argued that touch provides the greatest relative contribution, the experience of using an in-car switch is clearly multi-sensory and switch designs with inappropriate visual and/or auditory characteristics (e.g. garish colours, high frequency sounds) will inevitably be considered to be of poor quality.

6. ACKNOWLEDGEMENTS

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