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User-centered design criteria in next generation vehicle consoles

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Abstract

The purpose of this work is to gauge user opinions on vehicle dashboard design to ascertain the criteria important to consumers for the next generation of automobile dashboards. The results provide insight into the aspects of dashboard design that users feel are not beneficial and thereby lead to better informed dashboard designs in the future. Participants reviewed the physical ergonomics of their vehicles very positively. However, in dashboard design and instrument panel layout they were unsure of what an ideal dashboard would look like, often showing contradictory views. Controls on the steering wheel were also well reviewed but controls near the gear stick were not. In terms of vehicle technology Satnavs received good scoring for effectiveness but were reported as distracting. IVISs were negatively reviewed. Finally, automation was reviewed as potentially improving the daily lives of individuals but trust in automation is still a problem. Overall, this study showed that whilst dashboards are relatively well reviewed there are still issues to be addressed regarding in-vehicle technology and distraction, as well as improving public opinion on automated vehicles. Results represent the first stage in research studying current dashboards and distraction of in-vehicle technology and the design of automated dashboards of the future using virtual reality environments to create optimal console designs for drivers.

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Keywords: Design; human; design method; technology; automation

1. Introduction

At the introduction of the first automobile, the design and organization of the dashboard was no great challenge due to the limited amount of information to display and the lack of complexity of essential information [2], items such as speedometers were optional extras. However, automobile dashboards are now increasingly complex with diverse functionalities that aid vehicle control and allow the user to stay within the law in terms of behavior on the road. This is due to the advancement of in-vehicle technology and the large number of elements required by law to be displayed on a vehicle dashboard. As a result dashboards are a medium through which vast amounts of information can be obtained [11]. The challenge is to create dashboards incorporating all the functions and information whilst keeping the display simple, efficient, safe and promoting an excellent driver experience [6]. The design of car interiors relies on firm knowledge of both physical and cognitive ergonomics. Combining knowledge of optimum comfort levels and accessibility as well as the workload of operation, allows the creation of optimum vehicle interiors. In addition, due to the increased availability of automobiles and the competitiveness within automotive manufacturing, companies have to consider the customers by following a user-centered design process to understand the user, the user's goals and their opinions [11] on the design in order to create popular designs and provide a commercial advantage over competitors.

Furthermore, we are now at a stage in technological development where the potential for in-vehicle technology is vast [12], including the opportunity to create customized user experiences e.g. digital displays over mechanical ones as a user interface [20]. Therefore, it is paramount to understand the underlying mental processes associated with situation awareness and distraction due to existing vehicle technology [6]. Distracted driving due to the performance of secondary tasks is a major cause of automobile crashes [9], hence it is

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increasingly important for human factors research to design dashboards that reduce distraction related driving detriment.

Technological advancement has also led to the increased likelihood of an automated vehicle becoming the future of automobile development. Human factors research therefore has to consider not only the impact of current vehicle dashboards and existing vehicle technology, but also the impact of the emergence of automated driving dashboards and how consumers will respond to these [6].

1.1. Related work

The usability and ergonomics of vehicle dashboards is important to examine when considering the design and design improvements. A study in 2012 carried out a human response study to a range of car dashboards for ergonomic assessment and usability [2]. A basic, average and deluxe version of vehicle dashboard were used. The basic model showed serious problems with visibility of icons, understanding the meaning of symbols, complex and confusing instructions and the icons were too cluttered. The average model also showed unclear functioning of symbols, confusing instruments, captions appeared too similar and symbols that were unrelated to functionality. The deluxe model displayed serious problems in that a full knowledge of all the signs and captions was required to operate them fully and there was a lack of space for the luminous signs. Further problems included need for prioritization of instruments, understanding the captions and visibility problems. For usability, the basic model got no poor reviews whereas the medium and deluxe got two poor reviews. Problematically the study only used 4 volunteers, but the results have significance to research on automobile dashboards. From this study it is clear the design of automobile dashboards is still not optimum and the role of cognitive ergonomics in design is still to be fully explored and implemented regarding understanding and usefulness of dashboard elements.

More recently, an ergonomics-based design approach was used to assess helicopter instrument panels [1]. Their approach was based on established principles in determining the specific location and arrangement of components in a display; importance, frequency of use functional similarity and sequence of use. Interviews with pilots allowed for the evaluation of cockpit displays based on the frequency of use and ratings of importance as well as general opinions, preferences and experience with the display. The results of the interviews were utilized to create a range of optimized, alternative display layouts of flight instrument panels and better functional groupings based on user opinions. Finally the researchers were able to produce an optimum instrument panel arrangement for validation in future research [1]. Whilst this methodology was utilized for helicopter cockpits, similar principles can equally be applied to automobile interiors to help design more effective dashboards for drivers.

In addition to considering user opinions on dashboard design, it is also important to consider what users actually want and need from their dashboards. A recent study allowed participants to suggest ideas and create characteristics for future vehicles depending on the picture of the future the experimenter gave them [7]. They then used the conceptual vehicles to find constructs of user needs and then to group these into user need dimensions for use in the user-centered design process. The study revealed nineteen need dimensions: Automation, Calmness, Comfort & convenience, Connectivity, Control, Driver support, Trip context, Driving pleasure, Efficiency, Environmental impact, Freedom of choice, Interaction fluency, Ownership, Personalization, Safety, Self-image, Simplicity, Technology, and Versatility [7]. These suggest several important themes that need to be explored in design, such as how technology can and should support driving, the freedom of choice consumers strive to have and the role of the vehicle as part of a larger system [7].

1.2. Current work

This study aims to further work to assess user opinions on current automobile dashboard displays and the cognitive ergonomics of the design through a questionnaire. Participants will be asked about their experiences with their own dashboards in terms of usability and preferences as well as assessing overall dashboard layout and functioning to gain a picture of the current effectiveness of vehicle dashboards. In addition, usability, distraction and impact of particular dashboard technologies will be addressed. The questionnaire will also provide an insight into user feelings on the future of driving regarding automation. Results from the study represent the first stage in research that will look at current dashboards and distraction caused by in-vehicle technology and the improvement in designing automated dashboards of the future.

2. Method

2.1. Participants

Participants in this study were all students at Queen's University Belfast. A total of 35 participants completed the questionnaire. 25 were at undergraduate level and 10 were at postgraduate research level. There were 24 females and 11 males in the sample. Undergraduate students completed the questionnaire to gain course credit. Participant ages ranged from 18 to 40 years old. All students were required to have a Provisional or Full driving license at the time of the questionnaire so that all had driving experience. Only 3 participants reported having either their provisional or full license for less than one year (8.6%), whilst the majority reported having a full license between 1 and 5 years (65.7%) or 5-10 years (22.9%). One older participant held a license for 20-30 years (2.9%). 27 participants reported being frequent drivers. Most drivers reported driving less than 10 hours per week (62.9%) or between 10 and 20 hours per week (25.7%), reported driving less than one hour per week and 8.6% drove more than 20 hours per week.

2.2. Materials

Participants were required to complete a 50-item online questionnaire using Toluna Quick Surveys website. The questionnaire consisted of 3 sections. In Section A 12 questions addressed participant's opinions on the layout and design of car dashboards in terms of location and grouping and the physical ergonomics of their vehicles. Section B asked questions about the usability and distraction of in-vehicle technology and asked participants about their experiences interacting with the dashboard in terms of driving effects in 34 questions. Section C asked 4 questions about automated driving and asked participants their views on automated vehicles and the perceived effects they would have on their lives in the future.

The questionnaire took 25-30 minutes to complete and utilized a variety of answer responses, mainly rating scales and Yes/ No answers but also qualitative feedback opportunities for participants to give feedback about general dashboard design. Participants were given a corresponding email address to contact if there were any queries about the questionnaire.

3. Results

3.1. Physical ergonomics

Participants were asked to provide the make and model of the car they currently drive. This revealed a wide range of cars with the most popular being a Peugeot 206, followed by Renault Megane and Vauxhall Corsa. Other car makes included BMW, Citreon, Nissan and Volkswagen. When asked to rate individual aspects of the physical ergonomics of their vehicle participants responded very positively; *Comfort.* 48.6% of participants rated their comfort in their vehicle as Very Good, 43.9% as Good, 5.7% as Ok and 2.9% as Poor. No participants reviewed their interior comfort as Very Poor. *Ease of exit and entry.* 51.4% reported that the ease of entry and exit was Very Good, 45.7% answered Good and 2.9% answered that it was Ok. *Ease of reaching controls.* 62.9% noted this was Very good, 34.3% answered Good and 2.9% answered that control reach was Ok. *Visibility.* 42.9% answered that visibility was Very Good, 48.6% reported it was Good and 8.6% responded that visibility was Ok. There were no Poor or Very Poor reviews for the controls, entry and exit from vehicles or visibility. Participants were then asked to highlight factors in their preferred and least preferred vehicle in order to ascertain the factors important to participants. 16 factors were highlighted from participant answers; Handling, Comfort, Size, Advanced/ Modern, Fuel Economy, Visibility, Appearance, Space, Driving experience, Safety, Fuel type, Insurance cost, Complexity, Reliability, Control Access and Number of doors.

3.2. General Dashboard questions

Layout Participants were asked to rate the importance and frequency of use of a variety of vehicle elements. The mean value of importance and frequency were calculated and the difference was calculated (importance- frequency of use). The results are displayed in ***Table 1***. A negative answer means an aspect is used more frequently but is perceived as less important. A positive difference reflects an aspect that is important but is not used as frequently.

From ***Table 1*** the most important aspects of the dashboard for participants were the speedometer, low fuel warning, fuel gauge, indicators and high beam light. The least important aspects were the cruise control, the voltage gauge, in-vehicle information system, Satnav, climate control, clock and radio.

The most frequently used aspects were the speedometer, indicators, fuel gauge, radio and clock. The least frequently used elements included the cruise control, voltage gauge, airbag, in-vehicle information system and tire pressure. Participants then grouped aspects of the dashboard together and provided a reason for the grouping. These reasons were collated between participants and 10 factors were identified; non-essential (e.g. personal choice), essential, car status/ warnings, functionality, fuel information, safety features, aspects for communication with other drivers (such as lights and horn), climate control and weather conditions information. One participant answered that all aspects should be together as they are all important for driving.

Table 1 The difference in means of importance and frequency of use for various vehicle aspects.

Vehicle Aspect	*Mean Importance*	*Mean Frequency of use*	*Difference in Means*
Radio controls e.g. volume and tuning	3.66	4.29	-0.63
Clock	3.63	4.06	-0.43
Indicators/ turn signals	4.57	4.66	-0.09
Speedometer	4.77	4.69	0.09
Fuel gauge	4.63	4.40	0.23
Hand brake light	4.26	3.83	0.43
High beam light	4.57	3.94	0.63
Tachometer/ Rev count	4.11	3.40	0.71
Climate control functions	3.60	2.89	0.71
Windshield defrost	3.71	2.97	0.74
In- vehicle information system	3.26	2.46	0.80
Low fuel warning light	4.71	3.91	0.80
Seat belt reminder	4.29	3.46	0.83
SatNav/ GPS system	3.54	2.69	0.86
Mileage/ odometer	3.83	2.97	0.86
Cruise control	2.91	1.97	0.94
Fog beam indicator	4.09	3.00	1.09
Oil gauge/ Pressure warning	4.40	3.31	1.09
Voltage gauge	3.14	2.00	1.14
Open door warning	4.17	3.03	1.14
Anti-lock braking system (ABS) light	4.11	2.94	1.17
Hazard warning lights	4.54	3.31	1.23
Traction control warning light/ slip warning	3.89	2.66	1.23
Coolant gauge	4.00	2.77	1.23
Temperature warning	4.29	3.03	1.26
Engine management warning	4.20	2.94	1.26
Tire pressure	3.97	2.63	1.34
Front airbag	4.26	2.43	1.83

Participants identified characteristics a dashboard should and should not have. For desired characteristics of a dashboard participants highlighted 11 factors; provide means of communicating with other drivers, it must be simple, have clear symbols, be accessible, stylish, easy to understand, modern, not too distracting, uncluttered and organized. Participants also indicated dashboards must provide information on the car, your safety and your driving but that there must not be too much information or irrelevant information. Participants also disagreed on whether entertainment technology should be included and some suggested a Satnav should not be included. Some even said less technology is how dashboards should be. Participants also claimed dashboards should be well illuminated to have good visibility of the functions but not too bright. 2 of the participants stated they were happy with dashboards as they are currently designed and 2 participants reported they were unsure as to what a dashboard should/ should not be. 54.3% felt it would be beneficial for drivers to have an input into the design of the dashboard of their own dashboards. Lastly, participants were asked to rate their satisfaction with their current vehicle dashboards. 42.9% reported they were very satisfied, 45.7% reported satisfied, 8.6% were neither satisfied nor dissatisfied and 2.9% were dissatisfied. No participants claimed to be Very Dissatisfied with their dashboards.

Usability When asked to rate how simple their dashboard was to read and use, 54.3% answered Very Simple, 42.9% answered Simple and 2.9% answered quite complicated. 88.6% of participants reported they felt their dashboard helped them to drive better. All participants reported their dashboards were clear and easy to understand. However, 8.6% of participants reported that they are still not aware of all the functions of their dashboards, whilst the rest reported it was easy (45.7%) or very easy (45.7%) to learn all the functions. When asked if using the dashboard caused a detriment to their driving 97.1% reported it did not and that they were comfortable using these functions whilst driving.

The Instrument Panel 80% reported they felt that the instrument panel display did not have too many functions located on it but this dropped to 68.6% when asked if the information is useful to them specifically. 54.3% reported that they did not know what all the lights in the instrument panel were for. However, 34.3% of the participants reported that they felt the information on the panel was distracting to them whilst driving and 42.9% of the sample suggested they would redesign the instrument panel.

3.3. In-Vehicle Technology

The technology displayed on the center stack of participants' vehicle is appears to have been standard such as radio, clock, climate control, Satnav, in-vehicle information system, window controls and infotainment systems.

In-vehicle Information Systems- 8 participants reported having an in-vehicle information system (IVIS) in their vehicles. All participants were asked to answer the questions about an IVIS. 20.0% reported they would/ do use it whilst driving, 22.9% before starting to drive and 57.0% reported they never would/ never do use it. 65.7% also reported they would not find an IVIS useful. Furthermore, 31.4% reported it could have a Slightly Negative effect on their driving, whilst 68.6% reported it would have no effect. However when asked about the effect it would have on the safety of their driving, 40.0% suggested a Slight Negative effect, 51.4% suggested none, 5.7% answered Slightly Positive and 2.9% suggested Strong Positive.

Satellite Navigation Systems 7 participants reported having a Satnav system in their vehicles, one participant reported no but answered the Satnav questions anyway. 62.5% reported using their Satnav rarely, 25.0% very rarely and 12.5% never used it. In asked about the effectiveness of a Satnav, 12.5% strongly agreed that the Satnav was effective in taking them where they wanted to go, 50% reported they agreed, 25% reported they neither agreed nor disagreed and 12.5% disagreed with the statement. 37.5% agreed that the Satnav was easy to follow all the time, 50% neither agreed not disagreed and 12.5% disagreed. However, 75% of participants reported that the Satnav caused them to make a wrong turn when driving. The remainder of the questions were for those who did have a Satnav as well as those who did not. When asked if using the Satnav is/ would be a distraction 60.0% answered Yes. Finally, participants were asked what impact using a Satnav would have on their driving; 2.9% answered Strong Positive, 14.3% reported Slightly Positive, 37.1% suggested it would have No Effect, 42.9% answered Slightly Negative and 2.9% reported a Strong Negative.

3.4. Control locations

Gear Stick 6 participants had controls located around the base of the gear stick in their vehicles. The functions of these included window operation, the SatNav, temperature controls, Start/Stop for the engine and traction control and the cigarette lighter. 71.4% reported this location was not useful for controls but 77.1% reported this location is not a cause for distraction.

Steering Wheel 18 participants answered that they had controls located on the steering wheel. This was mostly to volume control, others included an information button, cruise control, Bluetooth and temperature control. 22 participants gave their opinions on the controls here with 51.4% suggesting that no changes be made to the controls on the steering wheel. Those that would change the controls suggested adding some as they are easy to reach. 82.7% suggested these were / would be useful to have. With regards to impact on driving 17.1% reported a Strong Positive effect, 37.1% Slight positive, 34.3% No Effect and only 11.4% reported a Slight Negative effect.

3.5. Automated Driving

When asked if they felt automated cars were the future of driving 8.6% responded Strongly Agree, 28.8% Agree, 40.0% replied they Don't Know, 17.1% Disagreed and 5.7% Strongly disagreed. *Safety* Participants rated how safe they felt automated vehicles were; 11.4% reported they were Very Safe, 54.3% reported they were Safe, 25.7% suggested Unsafe and 8.6% answered Very Unsafe. *Trust* 20.0% responded they would trust an automated vehicle Not At All, 40.0% would trust it a Little, 22.9% would trust it to some extent and 17.1% would trust it to a moderate extent. Participants reported the perceived impact an automated vehicle would have on their lives. *Driving related stress.* 25.7% responded automated vehicles would not change driving stress at all, 28.6% replied to a little extent, 22.9% replied to some extent and 22.9% replied to a moderate extent. *Driving enjoyment.* 40.0% suggested automated driving would have no impact on their enjoyment, 25.7% suggested a little improvement, 14.3% reported some improvement and 20.0% reported moderate improvement. *Level of mobility.* 28.6% suggested no change to their driving tendencies, 25.7% reported a little increase, 14.3% reported some increase and 31.4% reported a moderate increase in their level of mobility. The average response in each of the aspects fell in between a little and some extent of improvement for each. Showing most people feel automated vehicles would in fact improve their living to an extent.

4. Discussion

The overall aim of the current study was to assess public opinion on vehicle interiors, both in the realm of physical and cognitive ergonomics. The survey revealed a few expected results but also some surprising and even contradictory results for cognitive ergonomics.

With regards to physical ergonomics the majority of drivers are content with their vehicles. Only one participant noted that they felt their vehicle provided Poor comfort levels, however, the participant remarked this was due to their height. This is in agreement with literature suggesting the standard of comfort and physical position in the vehicle is in an optimum direction with specific dimensions and angles for driver position already established [13]. Although optimum may still be un-obtained due to customer-specific requirements such as age and repetitive head movements [19, 13, 10].

The factors highlighted by participants as important in their choice of automobile coincides with manufacturing companies advertising campaigns. Fuel economy, handling, technology and appearance are addressed and clearly the consumer desires aspects of these in their vehicles. The influence of advertising on consumer choice and decision making is well documented e.g. using brand names that correspond to product benefits cause an increased activation in decision making brain areas and are therefore more likely to be chosen [8]. The same can be applied to automobiles; highlighting benefits related to the above factors can increase the likelihood of purchase. Interestingly, reliability and safety were relatively unmentioned, reflecting consumers were primarily focused on the experience and feel of the vehicle, alternatively, drivers are confident vehicles are designed with optimum reliability and safety so do not concern themselves with these aspects.

When participants were asked to rate the importance and frequency of use of dashboard aspects the results showed that dashboard elements such as the Speedometer, Fuel gauge, Indicators, Low fuel light, High beam light, Hazard warning lights, Seat belt reminder, Hand brake light, Oil gauge/ Pressure warning and Temperature warning. As a result these should be, and are, in the immediate view of the driver. The remaining elements are factors that are viewed as less relevant for driving so should be perhaps moved to a location outside of the driver’s immediate field of view. This is already the case for some elements like the clock, climate control and Satnav. Perhaps some symbols and warning lights should be moved from the instrument panel to the center stack or IVIS. Prior work agrees as when participants draw the instrument panel from memory they merely draw the speedometer, rev count and fuel gauge with very limited acknowledgment of warning lights [16]. Thereby having less on the vehicle instrument panel is still desirable to consumers.

Participants displayed diverse and often contradictory opinions on what a dashboard should and should not be. For instance, some participants claimed modern entertainment technology should be included, whilst others argue it should not. Participants also exhibit a mentality that dashboards should not be distracting, cluttered or have too much information, but on the other hand argue for the inclusion of modern technology but not a lack of information and no irrelevant information. It is clear that drivers are unsure of what level of technology and information they want and need from their vehicle. The notion of no irrelevant information is complex; is any information provided on dashboards completely irrelevant? Perhaps participants were thinking of aspects such as entertainment when noting this factor. A limitation may be participant age and experience. Most were under 25 so had only a few years driving experience. More experienced drivers remember less from their instrument panels, so with experience their opinions of what is important in driving changes [16]. Most participants owned vehicles with relatively simple dashboards so likely had a lack of experience with more complex dashboards hence they are less likely to know the impact of more complex dashboards on driving.

Participants indicated a desire to have dashboard elements grouped. From participant responses it can be suggested that elements should be organized by being essential or non-essential then be grouped by functionality e.g. car status warnings etc. Grouping based on functionality has been shown to increase scanning speed and thereby would reduce the length of time drivers eyes would be off the road [14].

When asked specifically about the number of icons on the instrument panel, participants claimed that the display did not have too many functions, yet only 69% felt the information was useful. This is in contradiction with the 54% that claimed to not understand what all the functions were for and the 34% that found it distracting. This agrees with previous work that has highlighted problems with understanding the symbols used here [2]. 43% suggested they would redesign it, claiming that there were too many information sources and the display was cluttered and as a result most suggested the removal of some information that is irrelevant or unnecessary. Perhaps they are reflecting on experience and lack of use of various icons rather than the items being irrelevant.

Controls around the gear stick were reported to not be useful yet the majority of participants claimed this was not due to the distraction. Participants argued that taking their eyes from the road would be dangerous, others who thought they were useful claim they do not use them whilst driving or that they can cope with the multitasking it requires. The latter is supported by literature suggesting people found it easier to use buttons located here as they did not need to look at the location [5].

Steering wheel controls were quite positively reviewed, with some participants suggesting having more controls here would be beneficial. Participants suggested it would not take their eyes from the road, would be easy to find and would take less time to operate. Research has suggested that buttons located in the person’s line of sight caused less steering deviation and shorter off-road glances [4] making it a useful location for controls. Over 50% of participants felt they should have an input in vehicle dashboard design and some suggested introducing personalized panels which corresponds the rise in research on the introduction of personalized dashboards and that in general these are well received [20].

Satnav technology was viewed as distracting, often misleading and would have/ has a slight or strong negative impact on their driving, yet it was reported effective in taking them to their destination and relatively easy to follow. Current literature surrounding Satnav design shows that Satnavs do still pose a detriment to drivers when in use [17]. Participants responded that it decreases attention span for driving, interferes with your prior route knowledge, can be unreliable, can be hard to multitask with and causes glances away from the road. Participants felt IVISs were not useful, would cause a negative or no effect on their driving but would decrease their driving safety. IVISs also provide information about the maintenance of your vehicle, so perhaps participants are unfamiliar with this application. As a result it may be beneficial to make this aspect of IVISs more accessible to drivers, maybe incorporating less relevant aspects of the instrument panel to reduce clutter. That participants noted the possible distraction these devices cause contradicts literature surrounding multitasking ability which shows people have an inflated sense of ability to multi-task [18]. However, the increased awareness of the detriments to distraction could account for the discrepancy.

A problem for manufacturing companies is public opinion on the introduction of automation. This study showed that automated vehicles are still not entirely popular. Most participants felt these would be safe but would not trust them. Other research articles have suggested a lack of control and reliability could cause a lack of trust [3]. Furthermore, participants were largely unsure if this was the future of the driving experience but do concede that automated vehicles would have benefits to their daily lives such as reducing stress and improving their mobility. There was a divide on whether it would improve their enjoyment of driving, but perhaps with exposure to automation the benefits may be more readily seen.

5. Conclusion

This study showed that whilst dashboards are relatively well reviewed there are still issues to be addressed regarding in-vehicle technology and distraction, as well as improving public opinion on automated vehicles. However, because people are content with current dashboards it poses a problem of how changes to dashboards due to automation will be received by the public. With automation increasing, in-vehicle entertainment will increase and cause distraction, but how much distraction is enough and what is too much is something still to be answered by research. Future work could gauge opinions of experienced and older drivers (who experience cognitive decline) to show differences in usability and design criteria. The results of this study provide essential background information on issues surrounding driver experience and distraction to be used to improve future dashboard designs.

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