Influence of interaction designs of in-vehicle infotainment systems on drivers' preferences

Tomaž Čegovnik[1], Kristina Stojmenova[1], Sašo Tomažič [1] in Jaka Sodnik[1]

E-pošta: tomaz.cegovnik@fe.uni-lj.si, kristina.stojmenova@fe.uni-lj.si, saso.tomazic@fe.uni-lj.si, jaka.sodnik@fe.uni-lj.si

Abstract. *In this paper, we report on a user study where we compared three specific interaction designs: a multifunctional button on the steering wheel, touchscreen and freehand interaction. The button represents a traditional interaction design that proved useful in production vehicles; whereas touchscreen interfaces are very common in new vehicles and freehand interaction is considered as a promising interaction design for future use. In this study, we explored the influence on user experience, usability and user preference of three interface designs in different driving conditions, and for two different task difficulties. The results showed that in most cases the users preferred using the button interface for all of the driving conditions and task difficulties. The usability rating were in-line with the usability findings.*

1 Interaction

Interaction with in-vehicle information and multimedia systems is a very specific type of human-machine interaction (HMI). When designing HMI in vehicles, it is important to take in consideration that driving is the task that has the highest priority while operating the vehicle. The driver should never lose control of the road vehicle, even when interacting with other devices [1]. This applies to manual driving and to highly automated driving, where the driver still has complete responsibility for the driving task. Therefore, when designing user interfaces, we need to consider the drivers 'working' space and its limited ability to perform multiple concurrent tasks, which contributes to the usability of such systems. Furthermore, it is also very important to take into consideration the user preference and consequently their acceptance of the selected user interfaces and interaction designs.

2 Interaction designs

The most commonly used interaction designs in vehicles are tactile buttons, rotary buttons and levers, both on the steering wheel and on the dashboard. However, this type of interaction is suitable for a limited set of functionalities. With the increasing complexity of systems over time, the addition of new functionalities and digital displays, new concepts of HMI are emerging. Vehicles nowadays offer alternative modes of interaction, such as touch screens, multi-function rotary buttons, speech recognition, gesture recognition, hands-free interaction or touchpad [2][3].

When assessing the usability and user experience, it has already been found that performing tasks using freehand interaction can cause less errors, take shorter times to complete the task, and require shorter and fewer eye glances of the road compared to using tactile or rotary buttons [4][5]. Users rated freehand interaction as more enjoyable and found it less annoying compared to using a touch screen [5][6]. The most increasingly used interfaces in new vehicles are touchscreens. However, touchscreens have been associated with problems such as visual distractions and longer eyes-off-road periods. This has already been found in other studies, e.g. that the visual complexity of the managed touch screen increases with the reduction of buttons [7].

In this study, we were interested in the usability and user preference of using buttons, touch screen and freehand interaction for Slovenian drivers. Previous studies have shown that for example, British drivers found the touchscreen as a direct input device more usable than an indirect input device [8]. Another study found that US drivers drive safer using freehand interaction systems, but it causes longer completion times and a higher cognitive load [6].

3 Driving simulator study

The study was performed in a Nervtech [9] driving simulator. It had two factors – driving difficulty and task difficulty. The driving difficulties were easy, where only following a lead vehicle was required and difficult, where the driving required overtaking on the highway. In addition to driving in two different driving conditions, participants had to complete a list of tasks. The tasks were divided into two groups – easy and difficult tasks.

Each participant completed four sets of tasks – two different driving conditions and two different task difficulties. The order of driving modes and task difficulty were counterbalanced to eliminate the doubt of a learning effect affecting the results.

4 Methodology

4.1 Participants

28 participants (19 male and 9 female) aged 19 to 37 years (M = 24.3 years, SD = 3.9 years) participated in the study. All participants had a valid driving license with an average of 6 years of driving experience.

4.2 Interface designs

The interaction system in the simulator consists of two output channels and three input channels. The first output channel is visual and was displayed as a screen on the right side of the driver as in a real vehicle in the middle of the dashboard. The second output channel was audio feedback. Input channels were a touchscreen that was also the visual output channel, a button on the steering wheel and a freehand gesture recognition system.

The system allowed interaction through all three modes (hands-free interaction, button on the steering wheel or via touch screen) at all times. In the first part, participants were allowed to freely choose their favourite mode of interaction, in the second, they had to perform three tasks with a specific way of interaction determined by the experimenter, and in the last part were allowed to again freely choose the interface they prefer most.

4.3 Driving environment

During the experiment, participants had to follow a red vehicle in front of them all the time. The red vehicle periodically changed its speed between 110 km/h and 140 km/h so that the driver was actively involved in driving with dynamic vehicle tracking at all times.

The experiment was conducted on two driving scenarios with lower and higher difficulty. Both driving difficulties took place on a two-lane two-way highway separated by a fence. The difference in the two levels of difficulty was in the traffic density. In lower difficulty, there were no other vehicles in the direction of travel and infrequent traffic in the opposite direction. In difficult driving, there was also some traffic in the direction of travel - a few trucks at a distance of about 500 m, so that the red vehicle also overtook the other participants, and a few fast vehicles in the overtaking lane. This way of driving therefore also required monitoring other traffic in addition to the vehicle in front and was consequently more difficult.

4.4 Tasks

Participants' primary task was safe driving. They were instructed to follow traffic rules and try to drive as they would in real life. They were additionally asked to follow a specific vehicle with appropriate safety distance and to never overtake.

In addition to the primary task of driving, the participants also performed a list of tasks using the in-vehicle information system with all three interaction designs. The tasks were divided into two groups - easy and difficult. Easy tasks required less steps - a maximum of three to complete, while difficult at least five. An example of an easy task was turning on a specific radio station »`Radio -> Rock Radio`«. An example of a difficult task was turning on a specific song »`Media -> Music -> Nina Pušlar -> To mi je všeč`«.

Each participant completed four sets of tasks - two in different driving modes and two with different task difficulties. Each set consisted of 5 tasks: 1 with their choice of interaction, 3 with predetermined interaction design, and at the end one more with their choice of interaction. Half of the participants first drove on the driving scenario with lower difficulty followed by the one with higher difficulty, and the other half started with the one with higher difficulty, followed by driving on the scenario with lower difficulty. Each of these groups were further divided into two groups, with half of them starting the trials with easy tasks followed by difficult tasks and vice-versa.

4.5 Variables

We observed two dependent variables: user preference and usability. *User preference* was the frequency of interface design selection. In each of the four completed sets, participants had the possibility to freely choose from the three interface designs for the given task.

Usability was evaluated with task completion time and drivers cognitive load. Task completion time was defined as the time interval between the start of the task indicated by pressing the "Start" button when instructed, and the moment the correct function was selected in the IVIS. Cognitive load was assessed by measuring changes in the driver's pupil size during task performance and the time intervals in between tasks.

Additionally, we observed *driving safety* with standard deviation of lane position (SDLP) and eyes-off-road time. SDPL was defined as the deviation from the centre of the lane. Eyes-off-road was assessed with the eye-tracker.

5 Results

5.1 User preference

When participants had a free choice of choosing the interaction design, they preferred the button on the steering wheel (56.3%), followed by the touch screen (27.7%), and at last the freehand interaction design (16.1%). See Figure 1.

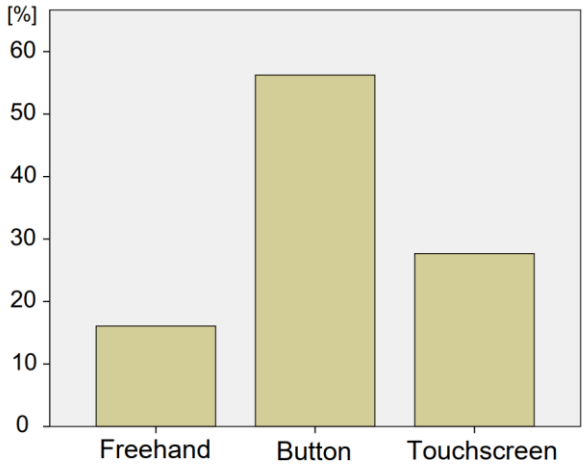

Figure 1. This figure shows how many user choose a specific interaction design.

5.2 Usability

As expected, we found significant effect of task difficulty on task completion time F (1,87), $p < 0,05$, where difficult tasks took more time to complete (M = 16,289 ms, SD = 10,431 ms) compared to easy tasks (M = 10,463 ms, SD = 4,732 ms).

We also found statistically significant effects of interaction design on completion time F (2,87), $p < 0,05$. Post hoc Bonferroni test revealed statistically significant difference in completion times with longest for the freehand interaction (21,787 ms), followed by button on the steering wheel (11,819 ms) and the shortest when performing the tasks using the touchpad (9,720 ms), figure 2.

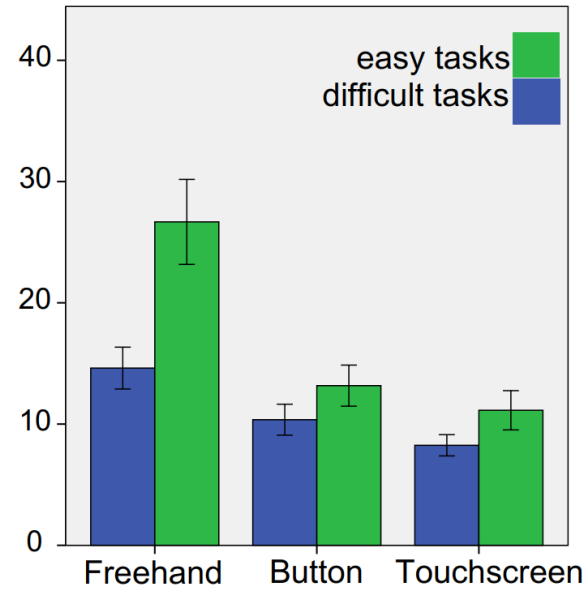

Figure 2. This figure shows the task completion time for easy and difficult tasks.

The results from the pupil dilation also revealed that cognitive load was higher when performing tasks in the driving scenario with higher difficulty (M = 0,06105, SD = 0,04674) compared to lower difficulty (M = 0,07567, SD = 0,04772), F (1,90), $p < 0,05$.
The mode of interaction also affects cognitive load F (2,90), $p < 0,05$. Post hoc tests revealed statistically significantly lower cognitive load while using the button on the steering wheel (M = 0,05327, SD = 0,03898) compared to using touchpad (M = 0,06814, SD = 0,04770) or freehand interaction (M = 0,077990, SD = 0,04438).

5.3 Driving safety

We found significant effects on SDLP only from the task difficultyF (1,36), $p < 0,1$. Difficult tasks (M = 0,1171 m, SD = 0,1989 m) caused higher SDLP compared to easy tasks (M = 0,8325 m, SD = 0,1569 m).

The other driving safety measure, eyes-off-road time, showed significant effects caused driving difficulty F (1,94), $p < 0,05$, where the time drivers looked on the road increased from the lower driving difficulty scenario (M = 0,67205, SD = 0,26028) compared to the more difficult one (M = 0,76276, SD = 0,19209).
The interaction design also had an effect on eyes-off-road time F (2,94), $p < 0,05$. Shortest times were found for touchscreen (M = 0,64369, SD = 0,25979) compared to button on the steering wheel (M = 0,72950, SD = 0,22035) and freehand (M = 0,78352, SD = 0,19058).

6 Discussion

When observed together, the results reveal that most people have chosen the button on the steering wheel as their preferred interaction design. The reason behind this can be discovered in the usability results, where this interface also proves to be the best. The results revealed the least preferred interface to be the freehand interaction, which is also the least useful, as it has high task completion times and results in high cognitive load. This results are in line with a study of US drivers, which also reported higher cognitive load and longer completion times for freehand interaction [6]. The second preferred device, the touchscreen, showed the highest usability results, which is in line with the results from other studies from for example Britain, where they found that a touchscreen showed a higher usability as a direct input device [8].
However, we find that safety related measures are not directly related to preference and usability, as users don't feel a direct impact on safety. The result of eyes-off-road time is expected, but it is not related to usability, as usability measures do not take into account the primary task of driving. We found the shortest eyes-off-road times in freehand and button interaction, and at longest via the touch screen.
Considering user preference, impact on driving safety and thus usability of the interaction designs, based on the results of this study, we can conclude the traditional button on the wheel to be most favourable for Slovenian drivers.

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Literature

[1] B. Pfleging, S. Schneegass, D. Kern, and A. Schmidt. 2014. Vom Transportmittel zum rollenden Computer – Interaktion im Auto. *Informatik-Spektrum* 37, 5: 418–422.

[2] Christian Müller and Garrett Weinberg. 2011. Multimodal Input in the Car, Today and Tomorrow. IEEE Multimedia 18, 1: 98–103.

[3] Andreas Riener and Michael Rossbory. 2011. Natural and intuitive hand gestures: a substitute for traditional vehicle control? Proceedings of the AutomotiveUI 11: 2.

[4] Kenneth Majlund Bach, Mads Gregers Jæger, Mikael B. Skov, and Nils Gram Thomassen. 2008. You can touch, but you can't look: interacting with in-vehicle systems. Proceeding of the twenty-sixth annual CHI conference on Human factors in computing systems - CHI '08, ACM Press, 1139.

[5] Lisa Graichen, Matthias Graichen, and Josef F. Krems. 2019. Evaluation of Gesture-Based In-Vehicle Interaction: User Experience and the Potential to Reduce Driver Distraction. Human Factors: The Journal of the Human Factors and Ergonomics Society: 001872081882425.

[6] Keenan R May, Thomas M Gable, and Bruce N Walker. 2014. A Multimodal Air Gesture Interface for In Vehicle Menu Navigation. *Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications - AutomotiveUI '14*, ACM Press, 1–6.

[7] Ayse Leyla Eren, Gary Burnett, and David R. Large. 2015. Can in-vehicle touchscreens be operated with zero visual demand? An exploratory driving simulator study. The 4th International Conference on Driver Distraction and Inattention.

[8] Catherine Harvey, Neville A. Stanton, Carl A. Pickering, Mike McDonald, and Pengjun Zheng. 2011. To twist or poke? A method for identifying usability issues with the rotary controller and touch screen for control of in-vehicle information systems. *Ergonomics* 54, 7: 609–625.

[9] nervtech | simuation technologies. *nervtech*. Retrieved March 25, 2019 from https://www.nervtech.com.