TOUCHPAD AS INTERACTION INPUT CONTROL FOR USE OF IN-VEHICLE INFOTAINMENT SYSTEMS

Stefan Norberg* and Professor Ulrike Rahe
Chalmers University of Technology, Division Design Department for Product and Production Development, A-huset, Sven Hultins gata 6 SE - 412 96 Göteborg, SWEDEN
Email: stenor@student.chalmers.se*, ulrike.rahe@chalmers.se

ABSTRACT

There is evidence that In-Vehicle Infotainment Systems (IVIS) with complex interactivity can distract the driver and that new interaction methods are needed. We report on and assess the suitability of a multi-touch touchpad controlled IVIS. In summary the results show that a rich multi-touch controlled interface can be developed that users accept and like, regardless of previous personal preference of touchpad usage. The results indicate that a bi-modal feedback system, either visual-audio or visual-haptic is needed to facilitate necessary driver control with regard to road safety.

KEYWORDS

HMI (Human Machine Interaction), Touchpad, IVIS (In Vehicle Infotainment Systems), automotive, interface design, multi-touch, gestures, usability, multi-modal

INTRODUCTION

In recent years the car industry has taken steps towards a more centralised interaction model for the IVIS functions. A measure to reduce clutter in the driver environment while maintaining safety and at the same time increasing the functionality [7]. This has typically been done with some kind of rotary control or touch-screen [6], with or without multi-modal feedback. When using a rotary controller the driver has to convert circular input movements to the intended linear movements of the cursor [7]. Research shows that display position has an impact on driver efficiency, if the display is placed far from the normal driving forward field of view, the driver's peripheral vision cannot be effectively used to detect unexpected events in front of the vehicle, which is the case for touch-screens [6].

However, using a touchpad as input device offers several advantages. Firstly, menu items and other interaction elements can be displayed with a better natural mapping [4], that makes the system more intuitive to use. Secondly, the display can be mounted in a high position with the touchpad separated from the display. A high display position has a smaller distance in degrees from the forward field of view, and less implications on refocusing the eyes compared to a lower display position [5]. Thirdly, with a touchpad, cursor movement is controlled in two dimensions by moving the finger in the desired horizontal or vertical direction [7].

The main purpose was to investigate the potential of a touchpad as the main interaction principle for IVIS and perform a subjective evaluation to investigate the user acceptance towards the technology. A conceptual design solution with multi-touch gestures was developed and evaluated to establish how well the concept could handle the challenges that comes with the next generation of infotainment systems.

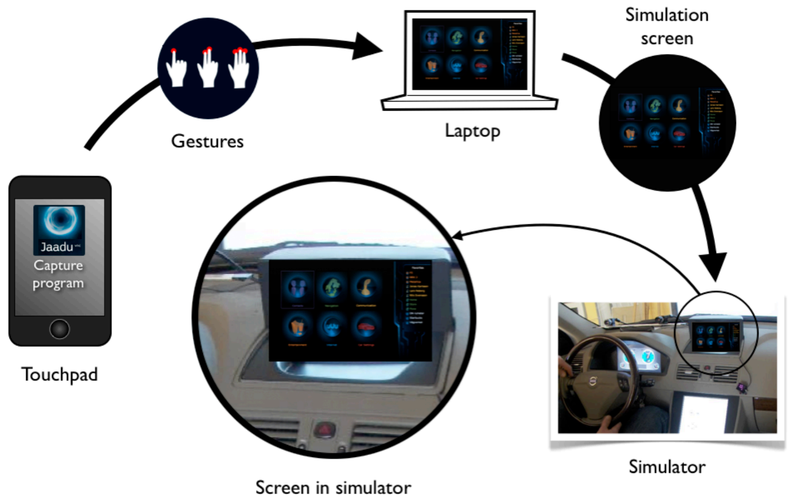


Figure 1 - Detailed overview of prototype set-up

METHOD

Process

The work was divided into three iterations which each consisted of a number of steps and a series of questions that needed to be answered. A brief overview on the agenda is listed below and the results from the last iteration will be presented in this paper:

- First iteration
  - Gather knowledge about the problem
  - Create a concept sketch to be implemented and tested
- Second iteration
  - Implement a concept
  - Test the concept in test vehicle
  - Test the concept in the simulator
  - Observe users and gather opinions from experts
- Third iteration
  - Create a graphic identity for the concept
  - Improve implementation after observations
  - Conduct user testing with experts and regular users
  - Identify further studies

Technology

Four basic parts were needed to build the concept:

- Capture program
- Touchpad
- Laptop
- Driving simulator/test vehicle

The capture programme handles gesture recognition and runs on the touchpad, which is an iPod touch. The touchpad sends the interpreted multi-touch gestures wireless as input to the simulation that runs on the laptop. The laptop is connected to the screen in the simulator or car which displays the simulation (see Figure 1 for an overview of how the different components were connected).

Test vehicle

Volvo Cars Corporation in Gothenburg has a specially equipped Volvo XC90 dedicated for use in clinics and user tests of driver environment and IVIS. All controls except those for driving can be connected to a laptop, which makes it possible to use the controls in the car as inputs to the simulation. The car looks and feels like any regular production car when driven, but it has some extra features. In the middle of the dashboard, neatly integrated, close to the windshield, a display has been mounted. The display is a bit larger than in a production car and it can be used to test graphics, interfaces and other visualisations under real driving conditions.

Driving simulator

The driving simulator was a fixed base simulator with the interior from a car, assembled in a room in front of projector screen. The display set-up in the simulator is very similar to the one in the test vehicle.

The driving experience in the simulator was a bit different from a real car, since there were no peripheral distractions and no real sense of speed either. Driving in simulators affect peoples judgement and make them overestimate their driving capabilities, compared to a real driving situation [2]. However, this did not affect the outcome of the experiments conducted, because user tests were focused on user experience and not task performance.

Concept

The tested concept consisted of a visual interface and a touchpad mounted between the front seats in the testing environment, behind the gear stick (driving simulator or test vehicle). The interface and was built to have a very wide menu hierarchy, as research shows that menu width is preferred over depth by users without negative impact on performance [3], [1]. The wide hierarchy was also an effort to reduce the number of choices imposed on the driver and give access to less and more important functions, instead of presenting a large number functions. At the same time an effort was made to create a logical grouping that made the interface as shallow as possible. A result of a wider hierarchy is a higher information density in each screen which is preferred by users over lower information density (see Figure 2) [1].

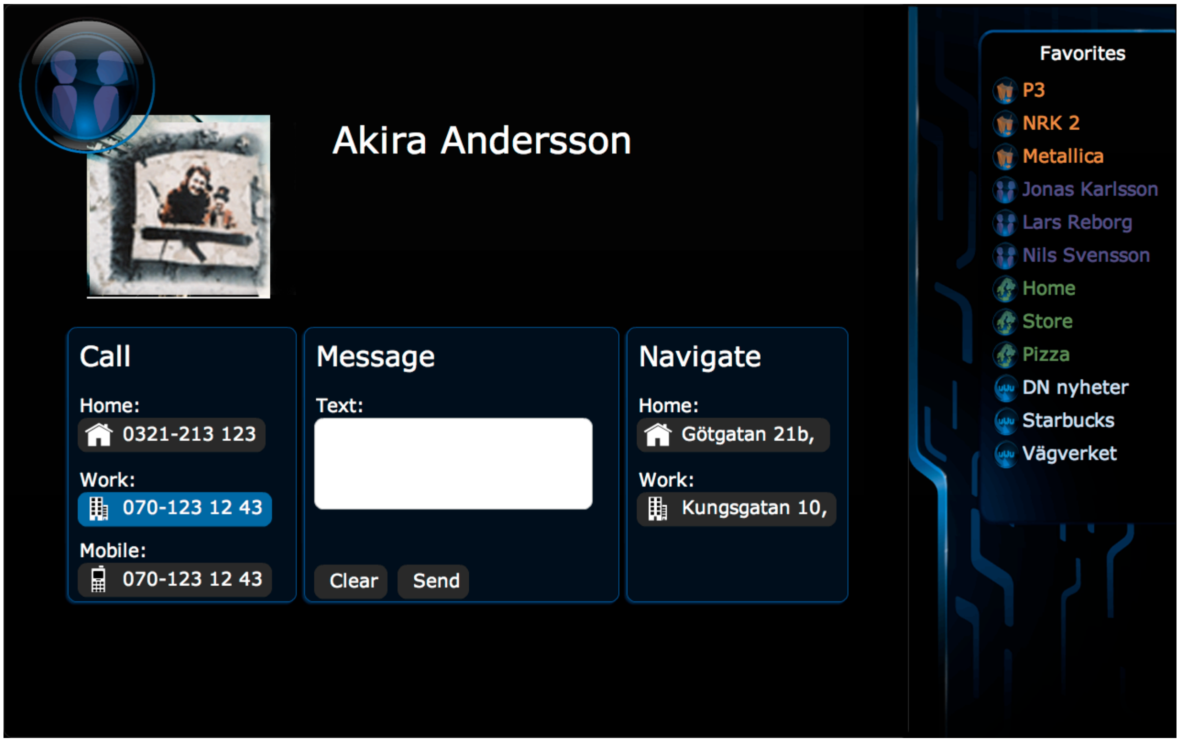
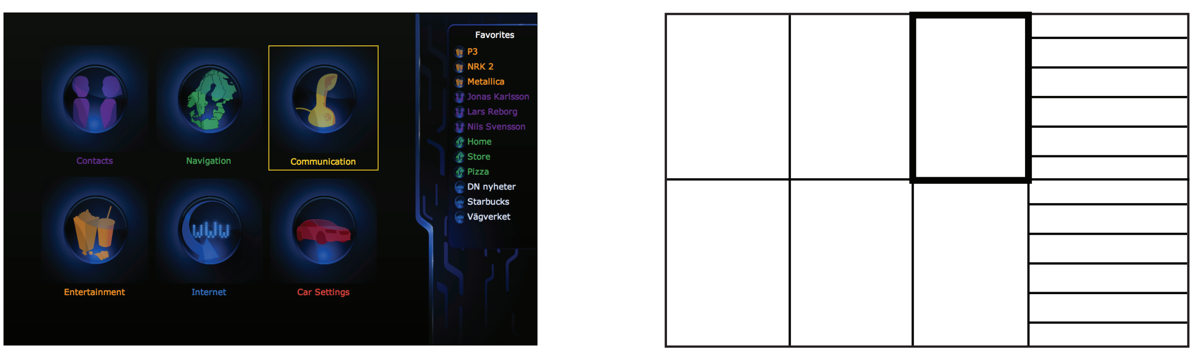


Figure 2 - Interface with wide hierarchy

Higg's law and Fitt's law was used to make the pointer actions easier for the drivers, and the selection on the screen was always active (the cursor could not "just disappear" as it sometimes does on a PC) in order for the driver to maintain control at all times (see Figure 3).



Graphic representation　　Corresponding hit areas

Figure 3 - The selection model with large hit areas

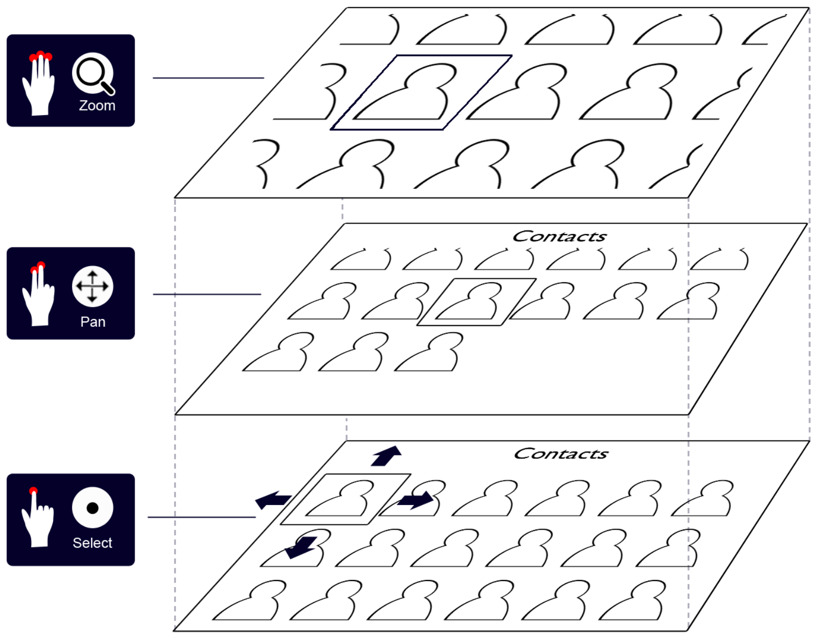


Figure 4 - Gestures used in the interface

The prototype was built to use three different gesture to control the functions in the IVIS. These forms the foundation for interacting with almost any imaginable application in the system in a standardised way.

A 1-finger gesture, i.e. regular pointing on a touchpad, was used to move the selection and alpha-numeric input by handwriting. 2-fingers were used to move and pan the different screens and 3-fingers were used to zoom in- and out in the interface, including on the map in the navigation view (see Figure 4).

The touchpad was equipped with a special home-button that took the user directly to the start screen which provided an exit at all times and prevented the user from getting lost in the interface. There was also a favourites bar that contained shortcuts to different functions e.g. way-points to “the store”, “the office”, “Radio station 1 - 107,3 MHz” so fourth (see Figure 2 and 3) by which the often used functions could be accessed, customised for the particular user.

Evaluation

User tests

The goal with the evaluation was to measure user acceptance and capture thoughts about what people think about using multi-touch interaction with a touchpad in an in-vehicle environment. The technical performance was not very good in the concept so it was decided not to test and measure performance, since it didn’t provide any significant value at that moment. Performance measures would be very important and interesting, but the numbers yielded from the experiment would unfortunately not show any valid results, since the controls lagged behind a bit. However, the conceptual performance was very good, with many interesting concepts available as described above. The participants in the evaluation consisted of two groups, one with experts and one with novice and they had these characteristics:

- Expert group
  - 9 participants
  - Expertise in interaction design or a field related to car industry
  - Education was on average a master degree
  - Age ranging from 20-60 years old
- Novice group
  - 7 participants
  - No particular correlation in background e.g. one person was a teacher, one a fashion designer, one a project manager
  - Education ranged from college to master degree
  - Age ranging from 20-30 years old

The evaluation was divided in to five parts and took approximately 90 minutes:

- Presentation of concept with screen-shots and explanations of the interaction model
- Questionnaire parts: Background and Touchpad
- Concept evaluation in in-vehicle environment (no driving or driving simulation)
- Questions that served as subject for discussion among the participants
- Questionnaire part: Prototype assessment

The results from this evaluation consisted of comments from the participants and the data from the questionnaire. Figure 5 on next page shows the average for the different parts of the concept. The coefficient of variation has been added to display the quote of the standard deviation to the mean (see Figure 6).

Figure 7 shows the correlation between the concept average and the touchpad average for each participant in the evaluation. The concept average was calculated from the prototype assessment answers from questionnaire and the touchpad average was calculated from the touchpad assessment answers from the questionnaire.

The solid line in Figure 4 shows that the slope of the concept average (y-axis) is very gentle as a function of the touchpad average (x-axis), which means that on average all users like the concept regardless what they think of working with a touchpad. The score would be on average at least 3.69/5 and at most 4.16/5 if the user disliked touchpad or liked touchpad respectively, that corresponds to a score between 7 and 8 on scale from 1 to 10. The character input method was disliked by novice users, probably because it was implemented with a relative pointing style that made it hard to use. To make the character input work well with the finger as stylus, the touchpad should operate with absolute pointing style as this is the natural way for humans to write with for example paper and pen. Another comment from novice users were the lack of support to spell words. Some of the novice participants explained that they used the keyboard (e.g. on a computer) as a tool to remember how to spell certain words, and that the lack of this made it hard to recall the spelling. This problem can be solved by adding a context aware spelling support, that shows word alternatives in a list, from which the user can choose an appropriate word. The experts liked the input method better that the novice, probably because they had previous knowledge of other input methods and saw an advantage in using the finger as a stylus.

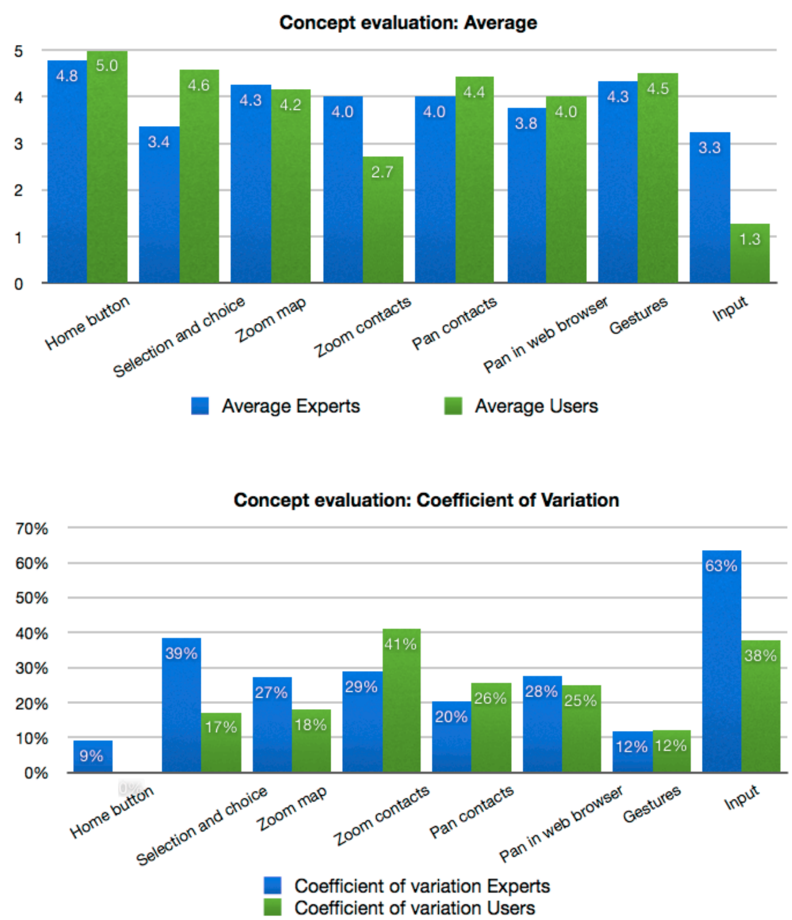


Figure 5 - Concept average with coefficient of variation

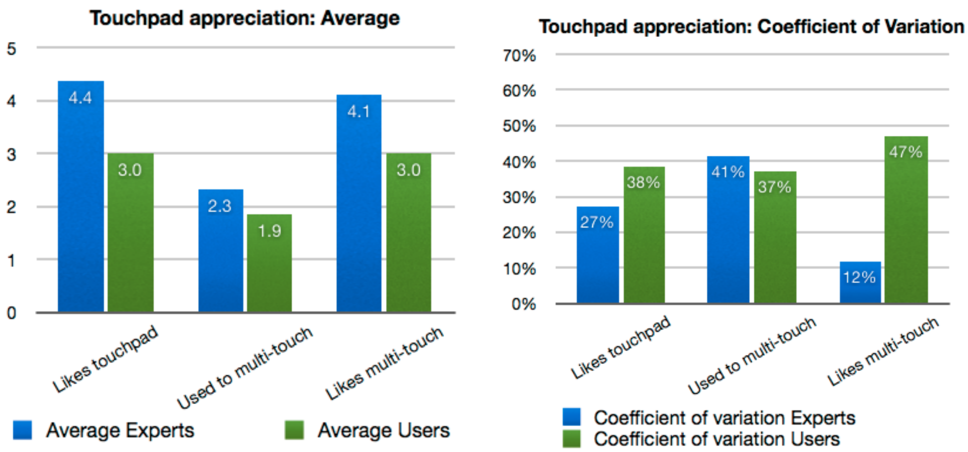


Figure 6 - Concept average with coefficient of variation

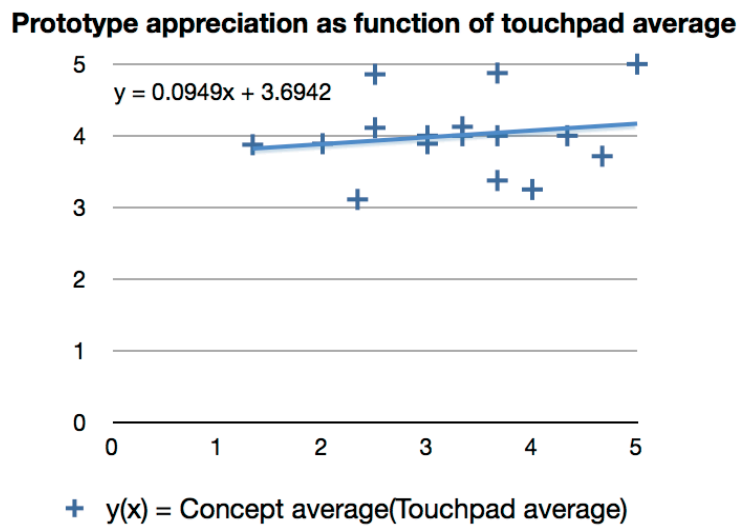


Figure 7 - Prototype appreciation average as function of touchpad average

Driving test

This part was performed by the author as only participant and therefore it does not provide any statistical significance. However, the results were nevertheless interesting and worth mentioning for future studies.

The test vehicle was used for a driving, to evaluate how the prototype handled in a real driving situation, compared to the more controlled environment in the simulator. The prototype was in the same state that previously had been tested in the simulator and the test consisted of a 30 minute driving session within the gates of Volvo's Torslanda facilities. The driving conditions can be compared to driving in a small city centre on a weekday with little traffic. There were some stretches of oncoming traffic, at speeds lower than 50 km/h and yielding to cars in some situations. Compared to the simulator this environment was more demanding and that made the system harder to use.

The previous results from the simulator indicated that the system worked fairly good, but the driving test turned out to be really interesting, as the experience differed a lot from the driving in the simulator. When driving a real car the impressions are much more vivid and the sense of danger is more real compared to the artificial danger in the simulator. It is easier to become overconfident in a simulator than in a real car, and overconfident driver behaviour has been observed in simulator studies [2]. Unfortunately, due to security regulations only the author could perform this testing, but it would certainly had proven to be a very useful test if more participants had been able to participate. However, the findings indicate that the final user-testing session ultimately should take place under real conditions, in the test vehicle, to get the best results, but unfortunately that was not possible.

- Cursor speed is extremely important to give the user control over the interface
- There is a tremendous leap from testing in a simulator to actually using the prototype in a vehicle, almost unbelievably large. After the driving sessions it feels like something designed in the office is almost bound to fail
- If the system feels “ridiculously easy” to use in the simulator it is probably just “easy” or “not hard” to use under real driving conditions

DISCUSSION AND CONCLUSION

Driving is a very physical experience with levels, buttons and forces acting on the driver. A touchpad is not tangible in the same way as almost all controls are in a car today and that is a challenge for using the touchpad as an input device. Utilising a touchpad as interaction input device for an IVIS system is definitely possible if the system has been designed with the advantages and disadvantages of using a touchpad in mind. At first the touchpad appears to be a bit brittle compared to other techniques, mainly because of the lack of physical properties. This can be compensated for by making a more dull control in the interface, which is possible since the sensitivity of a touchpad can be tweaked in a full spectrum from simple push button to high resolution control with multiple dimensions available trough the use of gestures. Necessary haptic or auditory feedback can be added to give the system a more tangible impression and better performance. A study investigating the effects of bi- and tri-modal haptic and auditory feedback in a touchpad controlled IVIS system concludes that bi-modal feedback was the most efficient, with auditory ranking slightly higher that haptic [7]. However, this might be a result of the participants being more used to auditory feedback and hence they responded better to that [7].

The use of a touchpad with multi-touch gestures gives access to many degrees of freedom in a natural way of interaction. How many depends on the number of gestures used. Three gestures have been proposed in this paper, which provides the basic interactions necessary for a complete IVIS system including unrestricted Internet navigation.

Some observations regarding ergonomics indicate that the touchpad surface texture has to be a bit rough to decrease finger to surface friction, which otherwise prevents the driver from controlling the system. The pad should be mounted in an angle with the front edge placed a bit lower that the back edge as it gives the user a consistent feeling of resistance, when swiping the fingers in the back and forward direction of the pad. A good armrest and wrist support has to be in place behind the pad to give the user proper control of their finger-movements.

The touchpad is not as solid as a physical control which results in more fragile interaction, which can be compensated for by adjusting the resolution and pointing style depending on application and driving situation. The lack of multi-modal feedback affects the interaction and demands very good graphic design to make the interface easy to use. A solution to this is to use two modes of selection, one coarse driving mode that strips the system of functionality and allows the driver to perform basic actions, and one finer mode that allows detailed manipulation e.g. dragging and placing a destination on the map when traffic situations allows that.

The trend to put more functions into the IVIS system without investigating the user requirements and the actual use of these functions should be considered to be revised. Very simple observation based studies can be performed to gather information, which can be used as a starting point for this work towards a more user-centred design process. Statistical data about user patterns should be collected to better design the system for the drivers. For example, mounting a small video camera in the ceiling of the car interior could be used to capture user activity and when the video is fast-forwarded the user patterns will emerge. This information can be used to reduce the amount of levels in the interface and information relevant for the context can make the system easier and less demanding to use. The favourites bar proposed in this paper works as a way to avoid complex menu navigation in a number of cases. This increases performance statistically over time, since functions often used can be accessed without entering any menu at all. In combination with the home button this makes navigation backwards in menus obsolete in the cases where a favourite is used. Character input should be reduced to a minimum as it is resource consuming. Spelling support and word suggestions should be provided to simplify the action

The age of the novice participants could have been spread in a wider range that 20-30 years old to possibly get a more varied result. The implications of their comparatively low age, might be that they are more susceptible to new technology and therefore gave the prototype a better grade in the evaluation, than an older group would have done

- The interface and the touchpad has to very responsive to be usable and for the driver to remain in control
- Haptic or auditory feedback has to be added to create a fully functional system in a real production car
- The driving test performed in the real car gave a very good perspective on how different a real driving situation is from an office environment. It is recommended that system- and interaction designers try out their prototypes in a real car during a prototype stage, to get an understanding of how one is affected by the system and what properties are important. The results are not trivial, for example, small animations can be very disturbing when driving. Though they seem

very subtle and informative and well designed in the office. Another example is colours, they might seem perfectly fine on a computer screen in the office, but in sunlight on a display made for a car they are too washed out to be useful. Yet another example is the effect of input controls, what sensitivity they have, how you operate them, etc. The control and the distractions you are exposed to, greatly affects the perception of a systems capabilities and weaknesses. In a real driving situation these are perceived much different from an office or simulator environment

In summary the results show that a rich multi-touch controlled interface can be developed that users accept and like regardless of previous personal preference of touchpad usage, but it should to be equipped with feedback in one more modality than visual to give the users proper control.

REFERENCES

[1] Johansson, H. & Walter, K. (2005) "InVehicle Screen-Density, Driver distraction and User Preferences for Low vs. High Screen Density in intergrated Display", Lindköpings Universitet, Sweden

[2] Jamson, A.H. & Merat, N. (2005) "Surrogate in-vehicle information systems and driver behaviour: Effects of visual and cognitive load in simulated driving", Transportation Research F, 8 (2). pp. 79-96. ISSN 1369-8478

[3] Landauer, T. K., Nachbar, D. W. (1985) "Selection From Alphabetic end Numeric Menu Treea Using A Touch Screen: Breadth, Depth, and Width", Bell Communications Research Morristown, N.J.

[4] Norman, D. (1988) "The Psychology of everyday things", ISBN 0465067093

[5] Olson, P. L., Dewar, R. E., & Alexander, A. J. (2002) "Human Factors in Traffic Safety", ISBN 0913875473

[6] Rydström, A., Broström, R. & Bengtsson, P. (2008) "Safety aspects of using multifunctional control interfaces while driving – a simulator study" Department of Human Work Sciences, Luleå University of Technology, Sweden

[7] Vilimek, R., Zimmer, A. (2007) "Development and Evaluation of a Multimodal Touchpad for Advanced In-Vehicle Systems", Engin. Psychol. and Cog. Ergonomics, HCII 2007, Springer-Verlag Berlin Heidelberg