I Feel it in my Fingers: Haptic Guidance on Touch Surfaces

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ABSTRACT

Touch screens are on the rise and replace traditional knobs and buttons at a fast pace. However, their lack of tangible guidance and feedback can become a problem in scenarios where visual attention is scarce. Besides dynamic tactile feedback by vibrations, the usability of touch screens can be improved by static haptic structures such as shaped or structured surfaces. In this paper we describe the prototype of an in-vehicle application using unimanual four-finger interaction and haptic guidance in order to avoid visual distraction from the primary task of driving. We built a low fidelity prototype with static haptics using an Android tablet and silicone foil. A user study showed that flexible positioning of touch buttons mapped to the user's fingers was more convenient and produced fewer errors than fixed positioning. A curved haptic border provided the user with orientation and allowed a new selection mode: dragging buttons over the edge resulted in a reduced interaction time when compared to double tapping. We present several different variants for unimanual multifinger interaction on planar and non-planar surfaces. Our results can support the development of future concepts for blind interaction.

Author Keywords

Automotive user interfaces, haptic guidance, prototyping, static haptics, touch.

ACM Classification Keywords

H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces – *Prototyping, Haptic I/O, Input devices and strategies (e.g., mouse, touchscreen), Interaction styles (e.g., commands, menus, forms, direct manipulation)*.

General Terms

Design; Human Factors.

INTRODUCTION

Touch screens allow a flexible presentation of information and user interaction and therefore increasingly replace traditional, static interfaces with haptic controls. Previously, hardware buttons and controllers provided the user with orientation, guidance and tactile feedback when selecting or adjusting values without the need to look. In contrast, touch screens lack a varied surface, haptic guidance and expressive tactile feedback. They rely on visual and audible information, with rare exceptions [10]. These attributes can become disadvantages or even security issues in situations such as driving a car. Here, visual distraction is avoided and any additional (ideally blind) interaction has to remain a secondary task. This is also enforced by recommendations for car manufacturers regarding interaction and glance times in order to ensure a low mental load [14]. Despite their downsides, more and more touch interfaces are integrated in cars. This fact demands for new interaction concepts with reduced visual attention.

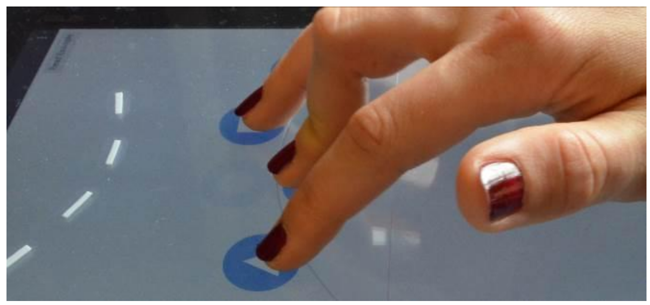

Figure 1. A silicon foil attached to a tablet forms a haptic border for guidance. It supports dragging gestures for item selection.

The interest in interfaces combining touch and haptic elements has been growing [2,10]. In such a new field, early prototyping is important, but in many cases not easy. However, simulating the interaction experience is a crucial step in order to explore ideas, gain insights and obtain empirical results in a short time [4]. So far, haptic design can be involved early in the process by using cheap and common buttons or materials such as modeling clay, paper, magnets, rubber bands and electronic devices for providing haptic feedback such as vibration [10].

The contribution of our paper is a range of interaction concepts for one-handed touch interaction with four fingers involving different haptic structures, supporting blind interaction on touch surfaces. We evaluated them using a low-fidelity prototyping method, enhancing off-the-shelf touch screen devices with haptic elements.

BACKGROUND AND RELATED WORK

Tactile feedback can support and confirm interaction with touch surfaces. It has been shown to increase interaction speed, reduce errors and also visual distraction [8]. This especially helps in situations such as driving a car, when multi-tasking and minimal visual distraction is required.

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Unimanual Multifinger Interaction

Most graphic touch user interfaces are static. The user has to approach the screen and tap a button to interact, which requires high visual attention. As shown by Azenkot et al. [1], who developed a blind text input scheme for touch screens using finger detection, this situation can be reversed by letting the button approach the user's finger when touching the screen, which requires less visual attention.

An intuitive and fast interaction principle, which has been successfully applied, is placing one or several fingers on a touch screen and confirming selection with an additional finger. By applying known principles from mouse interaction to multi-touch surfaces, Esenther and Ryall [7] developed a system in which the cursor appears and follows two arbitrary fingers placed on the touch screen. A right click is performed by tapping with an additional finger. Matejka et al. [9] found that right, middle, and left click is intuitive and fast when mapped to tapping with thumb, middle, and ring finger after positioning the index finger on the screen. Banovic et al. [3] investigated user performance on context menu selection using the thumb as well as the index finger for invoking the menu. Their study showed that the performance of selecting targets with multiple fingers simultaneously is better than traditional single finger selection, but also increases the number of errors.

Dynamic and Static Haptics

Dynamic haptics describe methods which generate tactile feedback only during an interaction and when needed, e.g., with electrovibration [2]. These methods improved interaction but driving vibrations could interfere with them in an automotive setting.

Static haptics describe features of touch surfaces which are persistent and do not change during interaction. Pielot et al. [11] used screen borders for orientation and guidance and found reduced interaction time and errors as well as increased perceived usability. El-Glaly et al. [6] added tactile overlays on touch screens to support access for the visual impaired. Patterns and landmarks of the overlay give tangible feedback, provide spatial references and improve locating areas on the surface. Roudaut et al. [12] investigated shaped touch surfaces with convex and concave bulges and showed that interaction differs if the surface is non-planar. It can ease the interaction by providing haptic guidance and can increase accuracy as well as subjective comfort. Shaped interfaces promise to improve touch interaction and can help when visual attention is restricted. Static haptics have been found to support the user very well. As a next step we want to create more complex interaction.

FINGER EQUALS FUNCTION

Currently a very common user interface in the car is a remote multifunctional control element placed on the center console. An advantage of this device is that the hand of the user can rest on the control element. Larger touch screens are mainly placed vertically on the center stack, thus frequent interaction can exhaust the arm. Therefore, we decided to investigate touch interaction at the position of the control element using the whole hand. The selection of a function happens with one of four fingers (except the thumb) while leaving the others on the surface. Considering the use case of a music player, symbols for the four main functions (play/pause, skip backward, skip forward and shuffle) are displayed in front of the driver. She now places the hand on the touch surface and selects play/pause with the index finger, skip backwards with the middle finger etc. The interaction concept transfers the mapping of conventional buttons to the fingers, thus the user, interacting blindly, knows which function is selected (*finger equals function*).

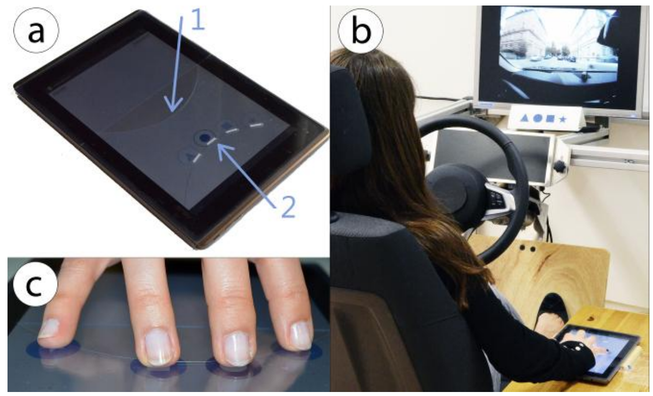

Figure 2. a) Haptic sharp (1) and smooth (2) edge attached to a tablet. b) Study setup with touch interaction at the position of current controllers. c) Flexible buttons along the edge.

Rapid Prototyping of Haptics

Developing interaction concepts requires early and iterative prototyping to "get the design right" [4]. Early prototypes for classical touch interaction can be made from paper, but applications on actual touch sensitive devices offer a more realistic exploration of concept ideas. Investigating a combination of touch and haptics would require building a prototype with a shaped or structured surface. In order to save time and money we used a rapid prototyping approach for several quick design iterations. We applied an approx. 0.5mm thick, cut out silicone foil to the cleaned surface of an off-the-shelf tablet. The foil is self-adhesive due to the vacuum between it and the surface. In addition, it was fixed with tape on the back of the tablet to prevent shifting during interaction. In this way we could add two different *haptic* structures to the tablet's multi-touch surface (Figure 2a): The cut out part of the foil forms a sharp, cascaded edge. The other edge is smoother and formed by covering four slim rectangles of thick material with foil. These provide graspable elevations from the surface and indicate the fingers' intended positions.

Touch Interaction

Functional prototypes for touch interaction can nowadays easily and quickly be realized on commonly available multi-touch devices and well-established development frameworks. We used a 10.1'' Asus Eee Pad running Android.

Traditionally, touch buttons are displayed in fixed positions. Alternatively, to decrease the required visual attention, we wanted to let the user approach the screen anywhere to interact and then provide functionality right where the hand touches. Therefore, our prototypes include two variants of *button positioning*. The buttons are either displayed traditionally in fixed positions or flexibly, adjusted to the fingers' touch points. The flexible positioning happens as soon as the user places the hand on the screen near or over the haptic edge. Buttons appear under the four fingertips and follow the hand when it is moved. This concept promises to require less visual attention than fixed positioning, because no visual search is required.

In addition, two *selection* alternatives were explored in our prototypes. A button can be selected by double tapping or by dragging it vertically down over the haptic edge (Figure 1). After a dragging gesture, the finger goes back to its initial position. Due to the *finger equals function* concept, both selection modes can be executed blindly, but dragging provides stronger haptic feedback due to the edge (Figure 2b). We decided for double tap instead of single tap because it promised to be more error robust when interacting blindly.

Button position	Flexible		Fixed
Haptics / **Selection**	None	Edge	Dotted
Double Tap	*FlexTap*	*FlexTapE*	*FixTap*
Drag		*FlexDragE*	*FixDrag*

Table 1. Overview of implemented combinations of button position, haptics and selection modes.

All prototypes (Table 1) were realized on one tablet using different screen areas. The sharp *edge* provides haptic feedback for *flexible* interaction anywhere along it. Thus it is combined with the selection modes *drag* and *double tap (FlexDragE*, *FlexTapE)*. The smoother, *dotted* edge is used for the *fixed* button positioning again with both selection modes *(FixDrag*, *FixTap)*. A prototype without haptics, *flexible* button positioning and selection by *double tap (FlexTap)* was included as a base line and to test the general necessity and convenience of a graspable structure.

EVALUATION

We evaluated the described prototypes in a user study with 12 participants (4 women) in the age of 20 to 40. The participants were students, Ph.D. candidates and employees in the field of computer science, psychology and human factors. They all use touch screens on a daily (92%) or at least weekly basis. The study setup consisted of an adjustable car seat and steering wheel without pedals (Figure 2c). Keeping costs low, videos of driving situations were displayed on a screen in front of the seat during task completion. In order to increase visual and cognitive attention towards the driving scene, questions about incidents along the route were asked afterwards. The tablet was placed on a table on the right side next to the seat. To remind subjects of the mapping between fingers and functions, a printed sign showed the four functions abstractly represented by four symbols in the area of a head-up display. Overall, the study took about 60 minutes for each participant.

We used a within-subjects design; the independent variable *prototype* contained five levels (Table 1) and the order was randomized per participant. For every prototype, there was an introduction phase including an example run for all four fingers. Then, the video started and participants were asked to focus their attention towards the driving scene. Each prototype was tested with 16 symbol selections in random order with all symbols equally distributed appearing four times. The symbols were announced by an audio command and a success or failure sound was played when the symbol was correctly or wrongly selected. The next symbol was given 3 seconds after a correct selection. The announced task was repeated immediately after a wrong selection.

Task completion time and errors were logged by an Android application. Glances towards the tablet and unexpected mistakes or other occurrences were observed and noted down by the researcher. After each run, a questionnaire containing evaluations of the interaction [5], workload (NASA TLX), as well as the subjective rating of usability, visual distraction, and errors was completed. In the end, a semi-structured interview was conducted to obtain comparative feedback regarding button positioning, selection modes, and the capability of each finger.

RESULTS & DISCUSSION

Overall, all prototypes were rated to be easy and well usable. Resting the hand on the touch surface was perceived convenient and less strenuous for the arm than interacting with vertical touchscreens. The significance level was set to 5%. A Friedman's ANOVA showed that the prototype had a significant influence on selection times ($\chi^2(4) = 14.87$, $p < 0.01$) and errors ($\chi^2(4) = 12.93$, $p < 0.05$). Flexible positioning in combination with drag and double tap (*FlexDragE* and *FlexTap)* were rated best and had the quickest selection times. *FlexTap* and *FlexTapE* had the least errors and glances during observation (Figure 3) and were rated best regarding the subjective rating by the participants in the questionnaire.

Flexible button positioning produced fewer errors than the fixed one. Moreover, it caused fewer glances when positioning the hand on the surface and during the interaction itself. Participants rated the flexible positioning better and easier to use. They felt less need to search on the surface and less required attention when interacting. Flexible positioning offered more freedom, no ergonomic constraints, and fit for all sizes of hands. Participants liked that they could determine the positions for interaction themselves.

The *selection* mode drag was quicker than double tap (Figure 3), but evoked mixed opinions. Some said it is ergonomic and convenient, since sliding over the surface is easier than lifting the fingers. Others said it is strenuous and unknown, thus not intuitive. Double tapping was perceived as fast and error robust, but also strenuous. Some participants would have favored a single tap or harder press. Unexpectedly, the tapping noise was thought to influence the product's character negatively.

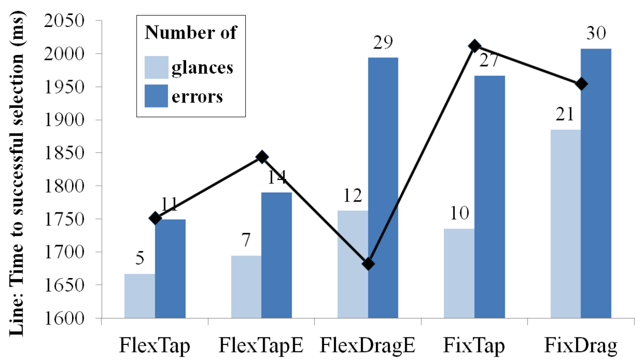

Figure 3. Selection times and observed errors and glances.

All participants were able to detect the *haptics* and to interact blindly. The two different types of edges were tangibly distinguishable. The feeling of the edges influenced the prototypes' characters and their final evaluation with the smoother edge being preferred. Comparing *FlexTap* and *FlexTapE*, the first showed fewer mistakes and glances. In general participants had no problems interacting without haptics and some even felt that the edge constrained them. The perceived glances were less and the blind interaction easier because no initial interaction position had to be found and less targeting effort was needed when selecting. Interaction without the edge gave the users a sense of freedom. Arguments in favor of the haptic edge were distinguishability of the surface and provision of tactile feedback. It creates a defined interaction area and offers help for finding it. Overall, these characteristics create a feeling of security.

Although all *fingers* were almost equal in speed of selection, index and middle finger showed less tracked errors and were rated better than ring and little finger. It was suggested to include the thumb due to its flexibility.

CONCLUSION & FUTURE WORK

We evaluated different blind interaction concepts for touch surfaces, partly involving haptics for finding buttons' positions as well as providing selection feedback. In order to do this, we used a low fidelity prototyping method for enhancing off-the-shelf touch devices with haptic structures. We found that our prototyping method was sufficient both for first quick and cheap iterations as well as for conducting a user study as we did not have any peel-off effect. Unimanual multifinger interaction promises to enhance touch interaction for in-vehicle systems. Haptic features can shape the product character positively. Our results however also show that static haptics are not necessarily needed for improving blind interaction. Touch surfaces offer flexibility regarding information display and interaction concepts. Car manufacturers and other researchers can use this freedom to make user interfaces dynamic, e.g. by flexible positioning of buttons mapped to the user's fingers. Nevertheless, haptic structures can serve as additional feedback in situations where this is required. In a different project, we even suggested designing interactions for future tangible interfaces related to their shapes' affordances [13]. Further steps will include more complex prototypes of non-planar touch interfaces with curves, edges and attached haptic elements to find and investigate new ideas for touch interaction in situations where low or no visual attention towards the interface is possible.

REFERENCES

1. Azenkot, S., Wobbrock, J.O., Prasain, S., and Ladner, R.E. Input finger detection for nonvisual touch screen text entry in Perkinput. Proc. GI, Canadian Information Processing Society (2012), 121-129.
2. Bau, O., Poupyrev, I., Israr, A., and Harrison, C. TeslaTouch: elec-trovibration for touch surfaces. Proc. UIST, ACM (2010), 283-292.
3. Banovic, N., Li, F.C.Y., Dearman, D., Yatani, K., and Truong, K.N. Design of unimanual multi-finger pie menu interaction. Proc. ITS, ACM (2011), 120-129.
4. Buxton, B. Sketching User Experiences: Getting the Design Right and the Right Design. Morgan Kaufmann, USA, 2007
5. Diefenbach, S., Lenz, E., and Hassenzahl, M. An interaction vocabu-lary. Describing the how of interaction. CHI Extended Abstracts, ACM (2013), 607–612.
6. El-Glaly, Y. and Quek, F. Touch-screens are not tangible: fusing tangible interaction with touch glass in readers for the blind. Proc. TEI, ACM (2013), 245–253.
7. Esenther A. and Ryall, K. Fluid DTMouse: better mouse support for touch-based interactions. Proc. AVI, ACM (2006), 112-115.
8. Hoggan, E., Brewster, S. A., and Johnston, J. Investigating the effectiveness of tactile feedback for mobile touchscreens. Proc. CHI, ACM (2008), 1573–1582.
9. Matejka, J., Grossman, T., Lo, J., and Fitzmaurice, G. The design and evaluation of multi-finger mouse emulation techniques. Proc. CHI, ACM (2009), 1073-1082.
10. Moussette, C. and Fällman, D. Designing for touch: Creating and building meaningful haptic interfaces. Proc. IASDR. International Association of Societies of Design Research (2009), 3605-3613.
11. Pielot, M., Hesselmann, T., Heuten, W., Kazakova, A., and Boll, S. PocketMenu: Non-Visual Menus for Touch Screen Devices. Proc. MobileHCI, ACM (2012), 327–330.
12. Roudaut, A., Pohl, H., and Baudisch, P. Touch input on curved surfaces. Proc. CHI, ACM (2011), 1011-1020.
13. Schmid, M., Rümelin, S., and Richter, H. 2013. Empowering materiality: inspiring the design of tangible interactions. Proc. TEI, ACM (2012), 91-98.
14. Visual-Manual NHTSA Driver Distraction Guidelines. Technical report, Department of Transportation - National Highway Traffic Safety Administration, 2013.