Writing to Your Car: Handwritten Text Input While Driving

Dagmar Kern
Pervasive Computing and User Interface Engineering Group
University of Duisburg-Essen
45117 Essen, Germany
http://pervasive.wiwi.uni-due.de
dagmar.kern@uni-due.de

Thorsten Appelmann
University of Duisburg-Essen
45117 Essen, Germany
thorsten.appelmann@stud.uni-due.de

Albrecht Schmidt
Pervasive Computing and User Interface Engineering Group
University of Duisburg-Essen
45117 Essen, Germany
albrecht.schmidt@uni-due.de

Nillakshi Pararasasegaran
University of Duisburg-Essen
45117 Essen, Germany
nillakshi.pararasasegaran@stud.uni-due.de

Jonas Arnsmann
University of Duisburg-Essen
45117 Essen, Germany
jonas.arnsmann@stud.uni-due.de

Benjamin Piepiera
University of Duisburg-Essen
45117 Essen, Germany
benjamin.piepiero@stud.uni-due.de

CHI 2009, April 4 – 9, 2009, Boston, MA, USA
ACM 978-1-60558-247-4/09/04.

Abstract
For in-car navigation, information and entertainment systems, text input is increasingly important. We investigate handwriting as a text input modality and assess where to best position the input surface and how to provide feedback. For this purpose, we created different prototypes that allow text input on the steering wheel and in the central console, as well as visual feedback on the input surface and on the dashboard. The results of the study indicate that handwritten text input on the steering wheel is well-received by the users and that the visual feedback should be presented in the dashboard area or on the steering wheel. We also observed that the number of corrective actions and the remaining errors were significantly smaller (25% less) on the steering wheel than in the central console and that entering text while driving made people drive slower.

Keywords
Text input, automotive user interfaces, car user interfaces, handwritten text input

ACM Classification Keywords
H.1.2 User/Machine Systems: Human factors. H.5.2 User Interfaces: Prototyping, Graphical user interfaces, User-centered design.

Introduction

Electronic maps and navigation aids, information and entertainment systems, and access to remote communications are common in modern cars. Such devices may be already integrated by the manufacturer or later added by the user. It is evident that using these new functionalities while driving increases driver distraction, and therefore, there are very clear rules about when they may and may not be used. This is reflected in many navigation systems, which present a warning that the driver should not interact with the system while the car is in motion. However, results of a 2006 survey conducted by Privilege Insurance in England show that 11% of all drivers claim to enter the destination after they have started driving [5]. Furthermore, we surveyed 20 navigation system users, and nearly all admitted to inputting text while driving, even though they are aware that this may be dangerous. This suggests that users have a desire for text input while driving and that in-car systems that only support text input in stationary conditions are not sufficient. Text input is very commonly used in cars (e.g. to input destination addresses in navigation systems), and upcoming applications (e.g. touchscreen media players, information browsers) will only increase the need for text input.

Current methods for text input in the automotive context concentrate mainly on three approaches: (1) touch-based direct input with on-screen keyboards, (2) tangible controls (i.e. physical knobs, sliders, buttons) with an on-screen keyboard, and (3) voice recognition. In contrast, our work looks at using handwriting recognition for text input. We address the following central questions that arise when designing a handwriting recognition system for use while driving: (1) Where should the input surface be located? (2) Where should the visual feedback be presented? (3) How does text input impact driving behavior?

In this paper, we report on experiments which compare different setups for handwriting recognition in a car cockpit. We created functional prototypes that allow text input on the steering wheel or in the central console and provide visual output on the steering wheel, the dashboard or the central console. We conducted a user study to explore the implications of these conditions and in particular their impact on driving behavior.

Related Work

Text input is also central to many applications outside of the automotive domain (e.g. desktop computing, mobile devices). In [4], text entry for mobile devices is discussed in great detail. Many aspects that play a role for mobile phones apply to the automotive setting as well; however, several requirements differ due to the constraints of the car cockpit. The size and distances between the user (from the driver’s seat) and the potential interaction surfaces are very dependent on the design of the car’s interior. Safety concerns in driving situations impose additional requirements on the design of user interface components and interaction methods.

In recent years, different means for alphanumeric input have been explored. González et al [3] investigated the use of EdgeWrite for destination entry in a car context. Sandnes at el. [6] offer a device with three chording keys mounted on the steering wheel. These approaches are promising but also have a major drawback: the drivers have to learn a new specialized interaction.

Figure 1. Study setup. Touchscreen displays on the steering wheel and in the middle console serve as input and output interfaces. Laptop serves as dashboard display (and speedometer). Large display shows first person view of the driving simulator.

Even if the interaction is very simple, this introduces a steeper learning curve for users. Voice recognition is a more natural way of inputting text. Several studies show the benefit of speech input over on-screen keyboards, e.g. [7], and this modality is available in many devices. User acceptance, however, is very low.

Our work builds on findings by Burnett et al. [1], who compared handwriting recognition to a traditional on-screen keyboard. Their findings show that handwriting recognition is generally superior to an on-screen keyboard. However, the location of the input device with regard to the dominant hand plays an important role. We took this as a starting point to explore further locations for the input and output interfaces.

Experiment

The results in [1] suggests that handwritten input is faster than interaction with an on-screen keyboard. Hence, we designed a user study to explore potential setups in a car cockpit. Keeping Burnett et al.'s [1] concerns regarding text input on a steering wheel in mind, we nevertheless decided to pick up their idea of having a text input interface mounted on a steering wheel, because it is the most independent position for left-handed and right-handed drivers in both right-hand and left-hand drive cars. Nowadays it is very common to have a multifunction controller knob input device in a car's center console, like BMW's iDrive controller or Mercedes MMI controller. In [3], the center console has already been used for handwriting recognition for search interfaces in cars. Thus, we decided to compare the steering wheel to the center console as text input interfaces under different feedback conditions (feedback on the active input interface vs. feedback in the dashboard display). Both input locations were easily reachable from the driver's seat.

Setup and Driving Simulator

In Figure 1, the overall setup of the hardware in the experiment is displayed. The setup was created to simulate a driving situation with a left-hand drive car, complete with a steering wheel and pedals. A first person view of the road is presented on a large screen (42" TFT monitor) and the speedometer and other instruments are shown on a dashboard screen (15" laptop display). Due to the construction of this setup, the driver would not be able to see a dashboard screen behind the steering wheel. Therefore, we decided to put the dashboard screen to the right of the steering wheel, like it is in some new cars, e.g. C4 from Citroën. In some conditions, this dashboard screen is also used to display visual feedback for the handwriting input (see Figure 3). For touch input, we used two 8" TFT color touchscreen displays. One display is integrated into the steering wheel (a Logitech racing steering wheel with a normal-sized steering wheel mounted on top). The other display is integrated into the center console to the right of the user. These displays are also used for visual feedback in some of the conditions.

For handwriting recognition, we used the Ink Analysis and Recognition API from Microsoft[1]. We developed test software with two different graphical user interfaces: *direct feedback* – the recognized character is directly shown on the same screen (see Figure 2) and *indirect feedback* – the recognized character is shown on the dashboard screen (see Figure 3). The written character is immediately shown in both user interfaces. In the

[1] http://msdn.microsoft.com/en-us/library/ms704040.aspx

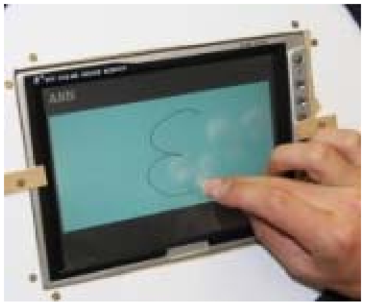

Figure 2. Graphical User Interface of the prototype *direct feedback*. Recognized characters are shown above the input area.

Figure 3. Graphical User Interface of the prototype *indirect feedback*. Recognized characters shown on the dashboard screen.

experiment, we restricted the handwriting recognition to recognize only single letters (A-Z and a-z) and backspace ("/"). If a text input is not recognized, a short audio feedback (beep) is provided; for recognized single characters, no audio feedback is presented. For completed words, a positive audio feedback is given.

In order to create a realistic driving situation and also measure the driving behavior and driving performance, we used CARS[2], an open source driving simulator for evaluating automotive UIs. In CARS, the layout of the driving environment (i.e. streets, intersections, lanes, traffic signs, and backgrounds) can be freely defined. While driving on the specified track, the simulator records data about speed and lane-keeping. Using a tool provided with the simulator, this data can be analyzed and parameters for the driving performance can be calculated. The environment used in the study was a track with straight roads, three left curves, three right curves and a intersection where the drivers have right of way. Speed limit signs next to the road indicated the assigned speed limit (e.g. 30km/h, 50km/h). The participants had to drive on the right side and there was no other traffic on the road.

Subjects
We recruited 16 participants (5 female) for the study. The average age was 24.88 (SD=3.36), and they were all right-handed. All participants carried a valid driver's licenses for 6.5 years (SD=2.81) on average. Regarding driving behavior, nine participants noted that they drive less than 10,000 km per year, four drive 10,000-20,000 km per year and three drive 20,000-30,000 km per year. All participants were used to driving left-hand drive cars. Their use of touchscreens, however, varied: six participants never work with touchscreens, one uses them regularly, and the rest use them occasionally.

[2] CARS - open source driving simulator, https://www.pcuie.uni-due.de/projectwiki/index.php/CARS

Study Design and Task
We chose a within-subject design with two independent variables: the position of the input surface and the position of the visual feedback. We explored four different conditions (input surface/visual feedback):

- steering wheel/steering wheel (sw/sw)
- steering wheel/dashboard (sw/db)
- central console / central console (cc/cc)
- central console/dashboard (cc/db)

The dependent variables measured were driving task performance, text input speed (character per minute or cpm), and corrections and remaining errors. For the driving task performance, we measured lane keeping (defined by standard deviation of the mean distance to the racing line) and average speed.

We used four counterbalanced sets of tasks that were randomly assigned to the different conditions. For the tasks, the input words compromised of 10 strings, alternating between addresses (street names and city names, e.g. *Berlinerstr Bonn*) and first names (e.g. *Anna*). Entering addresses is a common task in navigation systems, and entering names is common for finding contacts in the phonebook. The length of addresses ranged between 15 and 17 characters; names were 4 to 6 characters long. The total number of characters in each task was the same. In each task, the participants had to write (using a finger) the given text

input	output	speed	lane keeping
cc	cc	29.5	121.0
	db	29.6	103.5
sw	sw	30.7	104.6
	db	31.4	113.0
wt		33.5	87.9

Table 1. Average values for speed and lane keeping (cc = central console, sw = steering wheel, db = dashboard, wt = without task),

input	output	writting speed	correction actions & remaining errors
cc	cc	51.4	16.9
	db	57.6	15.1
sw	sw	59.5	12.7
	db	57.1	11.2

Table 2. Average values for writing speed and corrections and remaining errors (cc = central console, sw = steering wheel, db = dashboard).

strings on the specified touchscreen surface while driving. Participants were asked to maintain a comfortable speed, to stay in the right lane and to follow the speed limit.

Procedure

All participants were introduced to the setup. They each drove 5 minutes to get familiar with the driving simulator. Afterwards, they received an explanation of the text input task and were shown the different input surfaces and feedback locations. Then they had some time (~3 min) to try out the text input system until they were comfortable with it. Each participant then drove 5 minutes under each condition and without a secondary task. The order of the conditions was randomized. After the driving task, qualitative information was gathered from questionnaires and short interviews.

Results and Discussion

Driving Performance

To evaluate the driving performance for each research condition, we statistically analyzed the data gathered from the driving simulator with Students' t-test and looked particularly at the speed and lane keeping. The participants showed similar performance in lane keeping under all conditions (see Table 1). There were no significant differences in the measured deviation from the optimal driving lane position and the actually driven paths between any two conditions.

Looking closer at driving speeds, the data shows that participants drove significantly slower while entering text compared to driving without a secondary task (see Table 1). Students' t-test results: (*without task, steering wheel /steering wheel*), p<0.001; (*without task, central console/central console*), p<0.001; *without task, steering wheel/dashboard*) p<0.001; (*without task, central console/dashboard*), p=0.047. The conditions *steering wheel/steering wheel*, *central console/central console*, and *steering wheel/dashboard* were similar with regard to the reduction of speed: on average, the participants drove about 10% slower. The smallest effect on speed reduction (~5% slower) was observed in *steering wheel/dashboard*.

Text Input

The average text input speed, the corrective actions performed while writing and the number of errors are shown in Table 2. The input speeds for all conditions where the feedback is in the field of view (*steering wheel/steering wheel, steering wheel/dashboard, central console/dashboard*) are very similar. When the visual feedback is presented in the central console (*central console/central console*), the text input speed is on average slower; however, this effect is not significant. The number of corrections made and remaining errors are significantly smaller for entry on the steering wheel than for entry in the central console (Student's t-test, p=0.038, comparing *steering wheel/steering wheel* and *steering wheel/dashboard* to *central console/central console* and *central console/dashboard*).

Questionnaire Results

In the interview, we asked the participants about their preferences for the locations of the input surface and the visual feedback. 10 users selected the steering wheel as their favorite input location and 6 selected the central console. For the location of the visual feedback the participants were equally divided (8 for the steering wheel, 8 for the dashboard). Then we asked the

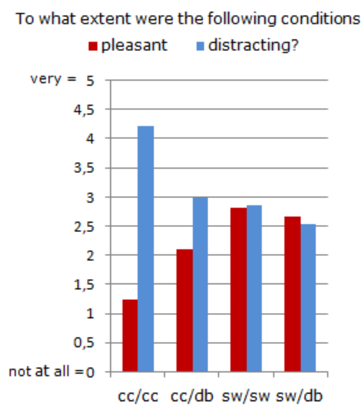

Figure 4. Subjective rating for distraction and pleasantness (cc = central console, sw = steering wheel, db = dashboard).

participants to rate on a scale from 0 to 5 how distracting they found the different conditions and how pleasant they found the interactions. The results are shown in Figure 4. The least preferred and most distracting condition was *central console/central console* (significantly compared to all other conditions). In the interviews, most participants stated that they found all other conditions rather similar.

Conclusion and Future Work

Text input while driving will inevitably impact driving performance. Our study shows that handwritten text input using fingers on a touchscreen mounted on the steering wheel is well accepted by users and lead to 25% fewer corrections and remaining errors compared to text input in the central console. We suggest a design where the input surface is on the steering wheel and the visual feedback is presented in the dashboard. The advantage of this design is that it could suit both left- and right-handed people, regardless of which side the steering wheel is. Nevertheless, experiments with left-handed drivers are required in the future to determine if this design does in fact suit them. The performance measures from the driving simulator study show no indication that entering text on the steering wheel hinders drivers' abilities in steering.

We want to take these first results as a starting point for future research regarding text input on the steering wheel. In future studies we plan to look closer into text input behavior while the steering wheel is turning. Do users input text while turning or do they interrupt their input? How high is the error rate while inputting text while turning? In future experiments, we also plan to analyze the visual demand of this interaction by observing eye gaze using an eye tracker. Using a head-up display for visual feedback may also be worth testing out in future experiments.

References

[1] Burnett, G.E., Lomas, S., Mason, B., Porter, J.M., Summerskill, S.J., Writing and driving: An assessment of handwriting recognition as a means of alphanumeric data entry in a driving context. Advances in Transportation Studies, 2005.

[2] González, I. E., Wobbrock, J. O., Chau, D. H., Faulring, A. and Myers, B. A. (2007) Eyes on the road, hands on the wheel: Thumb-based interaction techniques for input on steering wheels. Proceedings of Graphics Interface 2007.

[3] Graf, S., Spiessl W., Schmidt, A., Winter, A., Rigoll, G., In-car interaction using search-based user interfaces. Proc. of the 26th annual SIGCHI conference on Human factors in computing systems, 2008, Florence.

[4] MacKenzie, I. S. and Soukoreff, R. W. Text Entry for Mobile Computing: Models and Methods, Theory and Practice. Human Computer Interaction, 2002, Volume 17, pp. 147–198. Lawrence Erlbaum Associates, Inc.

[5] Privilege Insurance. Unsafe use of navigation equipment. http://www.privilege.com/aboutus/Unsafeusenavigation.htm

[6] Sandnes, F. E., Huang, Y.P., Huang, Y. M.: An Eyes-Free In-car User Interface Interaction Style Based on Visual and Textual Mnemonics, Chording and Speech. International Conference on Multimedia and Ubiquitous Engineering (MUE 2008), 24-26 April 2008, Korea

[7] Tsimhoni, O., Smith, D., and Green, P. (2004). Address Entry while Driving: Speech Recognition versus a Touch-screen Keyboard, Human Factors, 46(6), 600-610