Comparison of Different Touchless Gesture Interactions in the Car Cockpit

Diana Reich
Research training group prometei
Marchstr.23
10587 Berlin, Germany
+49 30 31429931
diana.reich@zmms.tu-berlin.de

Marcus Weber
Technische Universität Berlin
Straße des 17. Juni 135
10623 Berlin, Germany
+49 30 31429931
macus.weber@tu-berlin.de

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ABSTRACT
Nowadays, various assistance- and communication systems belong to the standard equipment of a modern car cockpit. Those days are gone where the whole infotainment-system consists of a traditional car radio with physical buttons and controllers. In recent years different new and innovative functions and features have been added in advanced car cockpits, e.g. navigation systems, Mp3-, CD- and DVD players. All of these infotainment functions need to be controlled by different human-computer interactions, e.g. spin controller in the center console, keystrokes or touchscreens. While interacting with these systems permanent visual attention on the display is imperious necessary to coordinate the finger for data entries. Therefore, diversions of gaze are provoked which could cause dangerous consequences while driving. Different studies reported negative user evaluations concerning usability, user satisfaction and distribution of attention while driving and interacting with different car systems (e.g. Lansdown, 2001; Ablassmeier, 2009). These studies were usually based on well-established, market-ready systems like spin controller and touchscreens.

But how should advance car systems be designed to enable effective and secure human-computer interaction while driving? One obvious and often suggested approach to interact with in-car systems is voice entry. But most of these systems are still buggy and not fully operative (Akyol, Libuda & Kraiss, 2001). But for some time past a new research area of cockpit interaction came up that focuses on intuitive, touchless gesture interactions within car cockpits. Researchers and developers expect advantages regarding distraction, efficiency and driving safety from it (Rees, 2013). Touchless gestures could be executed independent of the operator control module within three-dimensional room.

With our current research study we developed a navigation system prototype, which could be operated by humans through different intuitive, touchless gestures. Subsequently, we analyzed and compared three different ways of touchless interactions without any driving task to analyze very basic human-interaction abilities.

The user-defined task was to enter six predefined addresses (country/city/street), which were announced by the study manager into a navigation system. After each trial (3) the participants (n = 23) had to fill out the NASA-TLX questionnaire (Hart & Staveland, 1988). All participants had to operate with the navigation system in three different ways of touchless gesture interaction: (A) handwriting entries, (B) virtual keyboard entries (time) and (C) virtual keyboard entries (click) in randomized order. Virtual keyboard (time) means that the users had to pause 0,5 seconds above the interesting letter on the integrated virtual on-screen keyboard of Windows (see figure 1, above) to select this one. Virtual keyboard (click) needed a so-called „pinching“-pose (merging thumb and trigger finger) to select the interesting letter (see video for more details). For touchless handwriting data entries the „MyScript Stylus“ software of VisionObjects (see figure 1, below) was used. The software is able to transcribe handwritten data into formal text (on the navigation system interface).

Figure 1. On-screen keyboard of Windows (above) and MyScript Stylus input field (below)

Hence, the following hardware system environment was set up (see figure 2). A Microsoft Kinect camera was used as principal component to identify hand gesture interactions. The integrated software program „3Gear Systems“ allows a more precisely defined hand, finger and gesture detection. By integrating the application „Mouse3Button“ touchless mouse over interactions are possible by moving the right hand in the desired direction and the application supports the left mouse click function by the „pinching“-pose, too.

Figure 2. Experimental set-up and hardware system environment

Objective performances and subjective users' impressions were analyzed and compared with each other. The independent variable on doing so is the way of touchless gesture interaction (A, B, C) and the interesting dependent variables are: task completion time, task errors and subjective data (NASA-TLX).

Table 1. Average values and standard deviation of user performances and subjective data

	A	B	C
Time	1025s (348)	483s (120)	433s (144)
Errors	11,7 (8)	2,6 (3)	4,5 (3)
NASA-TLX	58,9 (22)	35,8 (17)	39,5 (18)

Because of technical issues six participants dropped out during handwriting condition (A), therefore only 15 participants were analyzed regarding objective performances (see video for detailed error description). *Task times* were analyzed using repeated measures ANOVA, with touchless gesture conditions (A, B, C) as independent variable. Thereby, significant differences were found between virtual keyboard condition B (time) and handwriting condition A, as well as virtual keyboard condition C (click) and handwriting condition A ($F(2,14) = 41.94$, $p < 0.001$, $n^2part = 0.75$). Both keyboard entries were obviously faster than handwriting entries (see table 1). *Task errors* were also analyzed using a repeated measure ANOVA, with touchless gesture conditions (A, B, C) as independent variable. Significant differences were found between handwriting and both virtual keyboard conditions ($F(2,14) = 16.28$, $p < 0.005$, $n^2part = 0.54$). Mean task errors were highest in the handwriting condition (A), compared to the keyboard conditions B and C (see table 1). The NASA-TLX questionnaire was used to analyze *subjective users` impressions* when interacting with the three different gestural conditions (A, B, C). Users rated the virtual keyboard conditions (B, C) more pleasant and less physically and mental demanding than handwriting condition ($F(2,21) = 16.92$, $p < 0.005$, $n^2part = 0.45$). Overall, no noteworthy differences between the two virtual keyboard conditions (B and C) were found regarding objective performances or subjective data (see table 1).

This study is part of a research series, which analyzes human-cockpit interactions in the automotive domain within virtual test environments. To do so, basic research is necessary regarding common and innovative in-car interaction modalities. Previously touch interfaces and center console spin controller were analyzed. Here, we examined the most promising touchless gesture input options for in-car navigation systems. In summary, the experiment showed advantages for touchless entries via virtual on-screen keyboards (time and click) when entering navigation destinations. They are significantly faster, more precise and less error-prone compared with handwriting gestures. Additionally, we recommend virtual keyboard gestures by click function (pinching pose) for dual-task conditions, because less visual attention should be necessary. But further research is required, especially while driving, before touchless gesture interactions could be implemented in real cars.

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