Optimal interface location and limits of gesture proficiency in an automobile

This paper explores the optimal location of gesture based in-vehicle technology for minimizing driver distraction as well as the specific manipulative gestures that would accompany such gesture based in-vehicle technologies. Three different vehicle locations and ten different driver gestures were evaluated during testing. Participants in the study performed each of the gestures at all three locations, and results indicated that most individuals preferred using the steering wheel location. Participants' responses indicated that they felt most comfortable with a repertoire of about five to seven gestures. Our initial findings suggest that gesture-based interface system might be most effective when placed at the three o'clock position on the steering wheel, and when the systems operate using a maximum of seven gestures.

INTRODUCTION

Fully integrated entertainment systems have become quite commonplace among many vehicles on the road today. This has lead to many vehicle manufactures attempting to develop their own unique systems. In order to set themselves apart, some car manufacturers have begun integrating touch screen inputs into their systems (e.g., MyFord Touch). With recent interest in gesture-based input (e.g., Pavlovic, Sharma, & Huang, 1997), some manufacturers have considered combining the touch-screen interfaces and entertainment systems.

One major issue that car manufacturers must address while designing these systems is where in the vehicle they should be located (Stevens, Quimby, Board, Kersloot, & Burns, 2002). Optimal locations for in-vehicle entertainment systems include areas that are easy to reach, do not impair access to other controls, and avoid accidental activation of the system (Stevens et al., 2002). Drivers need to acquire information from multiple sources and attend to relevant information while driving. If an in-vehicle entertainment system were to compete for these attentional resources, driving errors are more likely to occur (Horberry, Anderson, Regan, Triggs, & Brown, 2006). Thus, a gesture display that requires the user to take their eyes off of the road would be undesirable.

Being mindful of this issue, we set out to examine users' preferences for the location of a gesture-based input device. Keeping Stevens et al. (2002) guidelines in mind, we chose the following three locations: 1) the steering wheel, 2) center stack and 3) armrest (see Figure 1). All three positions satisfy the guidelines that controls should be easy to reach and not interfere with other driver controls (Stevens et al., 2002). We believed that individuals would prefer the steering wheel or arm rest locations over the center stack since they are both in closer proximity to the driver.

Our next point of interest related to the style and number of gestures that users would feel comfortable using while driving. We considered ten different gestures (See Figure 2) at each of the three locations. These types of gestures are known as manipulative gestures because they are used to interact with an object (Pavlovic, Sharma, & Huang, 1997). We hypothesized that users would be more comfortable using relatively common gestures (i.e. tapping) than uncommon gestures (i.e. letter drawing).

The present study reports the results of a collaborative effort with an automotive design firm working towards developing a gesture-based in-vehicle input system. Because of the sensitivity of the products they are developing, they asked not to be identified by name in this report, but consented to allow us to describe the human factors engineering techniques we are using, and some of the results of our efforts to determine the optimal location for new in-vehicle gesture-based input interfaces.

Figure 1. *The three white areas indicate the steering wheel (1), center stack (2) and armrest (3) test locations.*

Theoretical Prediction of Gesture Interaction Time

We used Fitts' Law and the Goals, Operators, Methods, and Selection Rules Keystroke Level Model (GOMS-KLM) to predict the amount of time it would take to interact with the interface at each location, and estimated the amount of time it would take for drivers to perform the 10 gestures we had identified. (MacKenzie, 1992, Kieras, 2001)

Fitts' law takes into account the distance between the starting point to the center of the target (D), and the width of the target along the axis of motion (W), (see Equation 1). Under Fitts' law both a and b are constants.

$$T = a + b\ log_2\ (1 + \frac{D}{W}) \qquad (1)$$

Utilizing Fitts' law, we were able to calculate an estimated time required to interact with each location. For the steering wheel location, the amount of time between the starting point and interface was determined based on when the thumb was used (585 ms), and when the pointer finger was used (1000 ms). For the center stack, the amount of time was determined by assuming the hands were on the steering wheel (1632 ms). For the right armrest the amount of time was determined by assuming that the right hand was on the steering wheel (2678 ms).

GOMS-KLM models sub-divide user interactions with interfaces into three general categories: physical, perceptual, and cognitive actions (Kieras, 2001). Based on extensive testing of expert users, each action is given an average duration. We also included an action derived from recent research on touch screen interfaces, which found that it takes about .23 seconds to swipe the finger on a touch screen (Holleis, Otto, Hussmann, & Schmidt, 2007). Table 1 illustrates the results of the GOMS-KLM for each of our 10 gestures.

METHODS

Materials

This research was conducted using a 2005 Toyota Camry. Gesture interfaces were secured onto three car locations: the steering wheel, center column, or the right armrest using Velcro adhesive strips. The steering wheel gesture interface consisted of an iPod Touch™ device with a covering on its face so that only a 2"x 2" square screen was exposed. The steering wheel interface was placed on the right hand side of the steering wheel at the three o'clock position so that it could be easily touched with the thumb when holding the steering wheel. The center console and the armrest gesture interface were tested using an iPad™ device with a covering over its face so that only a 3"x5" oval could be viewed. An application called Whiteboard was used to make sure that the gestures participants performed matched the gesture they were instructed to perform.

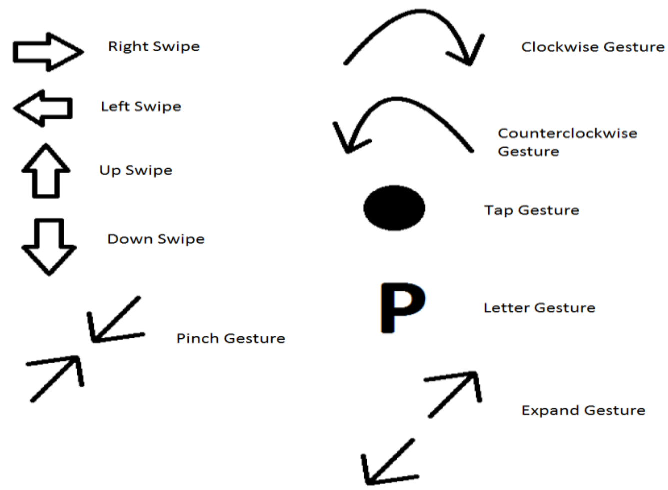

Figure 2. *Gestures used for testing*

Participants

We had six individuals (5 men, 1 woman) 23 to 28 years of age (M = 25 years) participate in this study. All were graduate students at George Mason University and had 5 to 11 years of driving experience (M = 8.33 years). All participants had prior experience with in-vehicle technologies.

Procedure

At the start of the session, participants completed a brief demographic questionnaire. Participants then sat in the driver's seat of the vehicle and adjusted the seat and steering wheel to their preferences. Participants were then shown a list of the ten gestures, which they practiced on the modified iPad™ device until they were familiar with them. Participants were then instructed to perform the gestures one at a time, answering two questions after each gesture. Each interface location was tested in this manner. After all three interface locations were tested; drivers completed a post-test questionnaire consisting of six questions.

All participants performed each gesture in the same order at all three locations. Location was counterbalanced using a Latin Square randomization.

Measures

Each participant rated the intuitiveness and ease of use after every gesture at each location using a seven point Likert scale (with 1 being low and 7 being high). Additionally, at the end of each location participants provided an overall rating of the gestures and the location using a similar seven point Likert scale. These questions evaluated ease of use, comfort, and estimated level of distraction while driving.

Swipe (left, right, up, and down)	Clockwise and Counterclockwise	Tap	Pinch and Expand	Letter (P)
Mental (1.2 sec)	Mental (1.2 sec)	Mental (1.2 sec)	Mental (1.2 sec)	Mental (1.2 sec)
Finger (.23 sec) Swipe	Finger (.46 sec) Swipe (2)	Press & (.10 sec) Release	Finger (.46 sec) Swipe (2)	Finger (.69 sec) Swipe (3)
Press & (.10 sec) Release	Press & (.10 sec) Release	NA	Press & (.10 sec) Release	Press & (.10 sec) Release
Total (1.53 sec)	Total (1.76 sec)	Total (1.30 sec)	Total (1.76 sec)	Total (1.99 sec)

Table 1. *GOMS-KLM of gestures*

RESULTS AND DISCUSSION

For data analysis purposes we collapsed the left and right gesture into LR, up and down into UD, clockwise and counterclockwise into clock, pinch and expand into zoom, and left the tap and letter gestures alone giving us six gesture types at each location.

Users rated the ease of the gestures highest in the steering wheel location (*M* = 5.92, *CI* = 0.40), followed by the armrest location (*M* = 5.14, *CI* = 0.52), and the center stack location (*M* = 4.92, *CI* = 0.39). This suggested that users perceived the gestures at the steering wheel as easier than at the other locations. Ratings of intuitiveness at each of the locations were similar, with high overall ratings of intuitiveness of gestures at each of the locations: armrest (*M* = 5.88, *CI* = 0.52), center stack (*M* = 5.66, *CI* = 0.36), and steering wheel (*M* = 5.81, *CI* = 0.49).

When the gesture evaluations were collapsed by location participants rated the ease of use highest for the tap gesture (*M* = 6.61, *CI* = 0.36), followed by similar ratings for the LR swipe (*M* = 5.72, *CI* = 0.59) and the UD swipe (*M* = 5.39, *CI* = 0.60), and the lowest ratings for the clock gesture (*M* = 5.00, *CI* = 0.57), followed by the pinch gesture (*M* = 4.72, *CI* = 0.61), and the letter P gesture (*M* = 4.50, *CI* = 0.66) (see Figure 3). An identical pattern was found for the evaluation of the intuitiveness of the gesture. This suggests that ease of use and intuitiveness of the gesture are highly related to one another, with more familiar gestures, such as tapping and swiping trending towards higher ratings and less familiar gestures, like clockwise ration, pinching, and letter gestures demonstrating lower ratings.

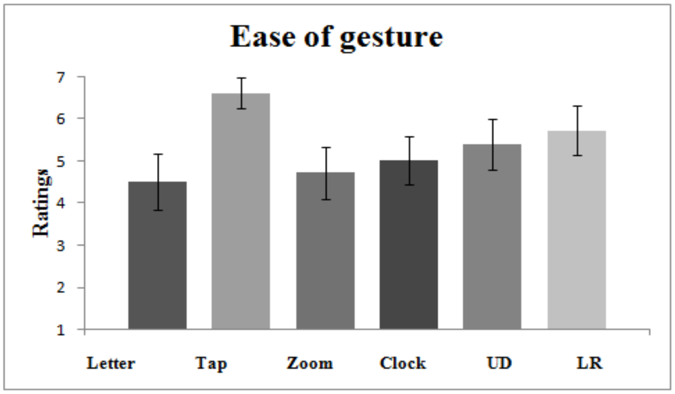

Figure 3. *User evaluation after performing the gesture*

The post-questionnaire confirmed the finding that there was a preference for the touch interface to be at the wheel location compared to the center-stack location and the armrest location. Participants rated the overall ease of use for the steering wheel location (*M* = 5.67, *CI* = 0.41) compared to the armrest location (*M* = 4.50, *CI* = 1.31) and the center-stack location (*M* = 4.17, *CI* = 1.06). Similarly, the comfort was rated as higher in the steering wheel location (*M* = 5.83, *CI* = 0.79) than the center stack location (*M* = 4.33, *CI* = 1.20), and the armrest location (*M* = 4.17, *CI* = 0.94).

A preference for the steering wheel was also suggested by lower ratings for the steering wheel location on how distracting it would be to use (*M* = 3.17, *CI* = 1.06), as compared to the armrest location (*M* = 4.33, *CI* = 1.57) and the center stack location (*M* = 4.67, *CI* = 1.20). Lastly, a preference for the steering wheel location was seen by higher rating for whether participants would want that particular gesture interface in their car (*M* = 4.67, *CI* = .41), as compared to the armrest location (*M* = 2.83, *CI* = .1.38) and the center stack location (*M* = 3, *CI* = 1.34). These results can be seen in Figure 4.

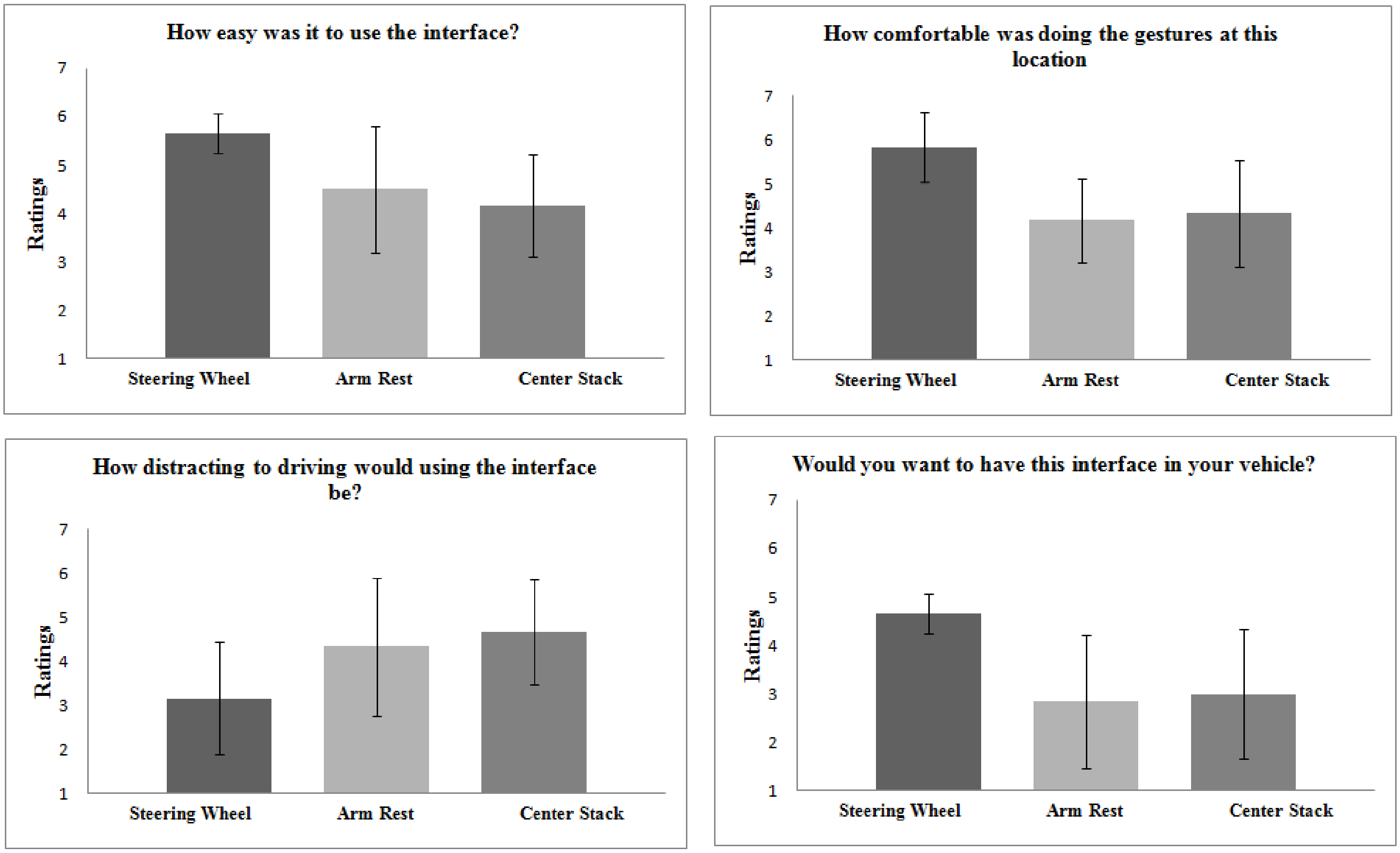

Figure 4. *Post-test questionnaire results*

CONCLUSION

Based upon our KLM and Fitts' law findings, we expected that users would find the steering wheel and armrest locations more intuitive and easier to use. Additionally, we hypothesized users would prefer gestures they were more familiar with.

Our results did not support the hypothesis that individuals would prefer the armrest; however, the results do provide some evidence that the steering wheel is a preferable location for gesture-based input devices. One possible explanation for why individuals did not like the arm rest could be that it was not adjustable for the individual, which may have resulted in an uncomfortable and unnatural position for interacting with this gesture-based interface. If the armrest were made to be adjustable, there may have been an increase in positive opinions about such a system being used in this location.

One other area of concern that warrants further investigation is how left handed individuals would feel about these locations, because all our participants were right-hand dominant. To address this issue, the designer could make the wheel based interface rotatable around the wheel so that if someone were left handed it could be moved from the 3:00 o'clock position to the 9:00 o'clock position allowing for them to easily be able to interact with the device.

Finally, we found some evidence supporting our hypothesis about the number of gestures that a user would be comfortable with. Users felt uncomfortable using the relatively more complex gestures (drawing a letter), but they were comfortable with frequently used simple gestures (swiping).

Our specific findings aside, this project demonstrates how task-analysis techniques can be used to make predictions about user performance and preferences for vehicle interface design. Product designers are often faced with difficult decisions about the types of interface designs that might best be utilized in transportation systems, and also where such systems should be located. The study presented here shows how basic task analysis and usability testing techniques can be utilized to provide designers with valuable feedback that may aid them as they make important decisions about the integration of new technology in vehicles.

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