A Study of Multi-touch Screen Installation in Vehicles for Single-touch and Gestural Operations

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\section*{ABSTRACT}

Touchscreens have been used for human-machine interactions in vehicle for years; researchers paid more attention to using touchscreen displays when driving was the primary task and the driving performance was the main concern. However, it is not legal to operate touchscreen devices while driving in most of modern countries. On the other hand, a driver may occasionally control in-vehicle systems through touch or even gestural operations on the touch display. The situation is becoming more and more popular and worthwhile further study. The current study investigated three different installations of a multi-touch screen in vehicle at high (around the driver's eye height in sitting), middle (around the height of the driver's shoulder) and low (around the height of the driver's waist) positions. Twenty-seven voluntary participants (aged 23.93±0.68 years old) were recruited to perform single-touch and gestural operations in a simulated car cabin. Their performance in accuracy for the two experimental tasks and subjective responses regarding difficulty, fatigue and preferences of the task and interfaces were recorded. The results of the study showed that, regardless of the single-touch target clicking task or the multi-touch target fitting task, the averaged errors over all target positions were the least for the middle installation and were the highest for the low installation. When user performance for different target sizes was compared in the gestural operations, participants tended to deviate more when the target size was small (100-pixel diameter) but manipulated the size more accurately when it was big (200-pixel diameter). The subjective evaluation through questionnaires showed that participants preferred the middle installation. The high installation was considered more difficult and caused greater fatigue on right neck, shoulder, upper extremities, wrist, and thumb belly areas. Based on the results of the current study, the middle installation is recommended for its higher accuracy and less fatigue. The upper installation, despite being recommended by other literature, caused greater errors, higher difficulty and fatigue, resulting the least preference. The difficulty and fatigue was not revealed for the lower installation, but it caused lower accuracy in gestural operations. This study could contribute to future design of in-vehicle touch interfaces in that the accuracy of single-touch and multi-touch tasks may be improved by installing the touchscreen at a middle height (around shoulder level). Future studies may consider verifying experiments in an interface simulating real in-vehicle information systems and increasing the number of data collected so that the result can be more applicable in reality.

Keywords: Touchscreen, Gesture, Interface Design, In-vehicle Information Systems

\section*{1. Introduction}

As touch technology advances, touchscreen displays become mainstream human-machine interfaces (HMI) in many daily life applications, e.g. cellphones, public kiosks, and in-vehicle information systems (IVIS). Although they were considered slower and less accurate (Maguire, 1999), they also provided flexibility in use, possibility to be customized and saved space (Sears, 1991). These advantages make them suitable for driving environment where the HMI tends to be versatile, customized and space-saving. However, previous studies related to in-vehicle display use seemed to focus on user performance in driving and neglected the fact that, in principle, it is forbidden to use the display and drive at the same time in most of modern countries. Wittmann et al (Wittmann, 2006) evaluated 7 different display locations in a simulated driving experiment and concluded that a position above the center of the dashboard was the best in lane keeping task. No manual operations on the display was involved so the recommendation was made considering only the secondary visual task, which is not applicable when operating in-vehicle systems are the primary task in a still vehicle. Toru et al. (Toru, Ryo, & Toshiro, 2013) investigated two screen installations: high and low positions, and their effect on...
driving when three different types of tasks were performed with driving. When a touch task (clicking on numerical targets according to their value in order) was performed, the low installation resulted in greater lane deviation. The accuracy of touch operations were not recorded in the experiment and gestural operations were not considered in the study either. The current study was interested in knowing how screen installation affect accuracy in touch and gestural operations because the information is not available from previous studies but would be useful for the design of IVIS since touch and gestural operations will be more common for HMI in future.

2. Method

An experiment was conducted to investigate the effects of three installations of touch displays on two experimental tasks in a simulated car cabin. The participants must hold legal driving licenses for six months or longer and have experience in using touchscreen devices (mobile phones, tablets, GPS devices, in-vehicle information systems, etc.) to assure their representativeness of target drivers of the study. Twenty-seven participants were recruited from the university community to perform single-touch and gestural operations. They were 19 males and 8 females aged 23.93±0.68 years old on average. Their participation was totally voluntary and their time was compensated.

Two experimental tasks, a single-touch and a gestural operation were performed by the participants. The single touch task requires them to click on 70 targets appearing randomly on different locations of a 1000X700 pixels screen areas (Figure 1). The gestural task requires them to use a pinch gesture to size and move 54 circles to fit their respective targets (Figure 2). In addition, there were two target sizes in the gestural task: 100 and 200 pixels in diameter. Therefore in the gestural tasks there were 108 operations to be completed.

The abovementioned experimental tasks were performed on three 10.1-inch multi-touch displays installed at three different positions: high, middle and low (Figure 3). The center of the middle display was vertically aligned with the midline of the steering wheel and separated from the other two displays by 20.6 centimeters. The three touch displays were located 17 centimeters away and 31 centimeters to the right of the center of the steering wheel. The spatial layout was designed to reflect right-hand traffic (left-side drive) and typical interior space of cars in Taiwan. Also the height of the screens were designed so that the center of the upper screen was aligned with the 50%ile eye height in sitting of Taiwanese population.

Before the experiment, the participants were allowed to adjust the distance between their seats and the steering wheel as well as the inclination of the seat and the steering wheel to obtain the most comfortable posture. After a short practice of each experimental task, the participants started to perform each formal experimental task twice on touch displays installed at three positions in...
random order, and therefore each participant completed 12 trials (2 tasks X 3 installations X 2 repetitions) with 3 to 5 minutes breaks in-between. They were asked to do the task both accurately and precisely while their performance in accuracy, i.e., the deviation from target centers (errors) and from the desired target size (errors in diameters for gestural tasks only), were recorded by the C# computer program and statistically analyzed by Minitab® software. During breaks, they also filled in questionnaires to report subjective opinions about difficulty, fatigue and preferences of the task and installations.

3. Results

The result of analysis of variance (ANOVA) for errors in the single-touch task is shown in Figure 4. The middle installation appeared to produce better performance in accuracy ($F(2,230)=4.38$, $p=0.014$). Further post-hoc comparison showed that performance on low installation was significantly worse than that on middle and high ones (letters in parenthesis represents Tukey’s grouping, Figure 4). A closer inspection of the data revealed that participants deviated more in Y-direction (vertical movements) using the low installation.

Similarly, the ANOVA revealed that the middle installation was significantly better than the lower one in terms of overall accuracy in Figure 5 ($F(2,291)=6.69$, $p=0.001$). Post-hoc comparison also showed that performance on low installation was significantly worse than that on middle one but not high one (letters in parenthesis represents Tukey’s grouping, Figure 5). In contrast to the finding for the single touch task, participants performed much worse in x-direction (horizontal movements) using the low installation.

Regarding the effect of the target size in the gestural task, the smaller target (100 pixels in diameter) caused higher deviation in translation from the target center (Figure 6) but was more accurate in size manipulation (Figure 7).

Although the high installation produced comparable performance with the middle one (Figure 4 and 5), results from subjective questionnaires showed that it is inferior to the middle one in terms of difficulty in use, fatigue and preference. First, Figure 8 showed that the high installation was considered the most difficult one to use. Second, participants reported significantly higher fatigue in shaded
areas in Figure 9. Finally, only one participant favored the high installation over others, while 18 over 27 participants preferred the middle installation. Therefore, the high installation was the least one to choose if subjectively evaluated.

![Figure 8. The effect of target size on sizing errors](image)

![Figure 9. The fatiguing areas using the high installation](image)

### 4. Conclusion

The current study investigated the installation of in-vehicle touch displays and their use in touch and gestural tasks. The results recommended the use of the middle installation (around the shoulder height and aligned with the midline of the steering wheel) because it produced relatively better accuracy in both singe touch and gestural operations. It was also regarded as one of the easiest installation to use and the most favored one. The high installation, despite being recommended by previous research, was found difficult to use subjectively and caused fatigue in many upper body areas. It was speculated that while the high installation facilitated simultaneous visual tasks in driving, its height might require participants to elevate their shoulder and thus they felt more fatigued. Therefore in context of in-vehicle system operations without driving as the primary ask, the middle installation should be used. The low one was the last choice in terms of performance but interestingly more liked than the upper one. The reason might be that the participants leaned their bodies forward instead of stretching upper extremities to reach relatively distant display in low installation. The posture may be less fatiguing but taxed on accuracy in vertical movements of single touch operations and in horizontal movements of gestural operations. Therefore the low installation should be the least if accuracy is a critical concern in the design.

Another useful finding that can be applied to the interface design in vehicle is the effect of target size in gestural operation. The smaller object (100-pixel diameter) could be sized more accurately but the bigger one (200-pixel diameter) was moved more precisely. Possible explanation of this phenomenon can be that the bigger circular object provided clearer visual reference (less blocking by fingers) while participants encountered less difficulty (caused by biomechanical restraints in finger span) manipulating the smaller one. According to this finding, a bigger target should be adopted when the movement precision is more important and a smaller target should benefit object manipulation in size. This suggestion, however, requires future research to confirm its assumed effect and hidden mechanism in a more realistic setting, e.g. a road test on simulated touch in-vehicle information systems. Nevertheless, more data relevant to touch and gestural operations in still vehicles are needed to realize practicality of using multi-touch interfaces for human-machine interaction in driving environment.

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### References


