The Effects of Input Devices on Driving Tasks

By:

Ian Gibbs
Amy Grude
Roger Marin
Gwen Sutter

Instructor: Paul Green

February 9, 2004

TABLE OF CONTENTS

INTRODUCTION

Currently, there is interest in integrating computing devices into automobiles to enable driver data entry. Since these devices will be used in a car, it is reasonable to assume that the drivers will be using them in addition to driving the car. This presents a possible problem of individuals attempting to do two simultaneous visual/mechanical tasks at the same time. In order to understand the implications of the integration of computing devices into cars, it is important to study the effects that a secondary data entry task will have on a primary driving task for various subjects. Another key aspect is how elderly-driver performance will be affected by their use of computing devices.

A previous study by Paelke (1993) illustrated the detrimental effects of destination selection via several touch-screen input devices on a simulated driving task for both elderly and younger users. Therefore, it may be possible that there is a difference in performance between simulated interfaces via touch-screen devices and tangible interfaces. This report will examine user performance with the dual tasks of driving and data entry into various types of computing devices for both elderly and young users. Two questions will be addressed:

1. What is the effect on user driving performance while using input devices?

2. How do different devices compare to each other with respect to user driving performance?

TEST PLAN

Test Participants

There were two groups of participants. The "Old" group consisted of people over the age of 40 and the "Young" group consisted of people between the ages of 16 and 40. All participants volunteered and were not paid. All testing was completed on Friday February 6th, 2004 and Saturday February 7th, 2004.

The first "Old" participant was an 85 year old, female resident of the 'Sunrise at North Ann Arbor' assisted living center. She wore glasses, was right handed, and was not a touch typist (in this paper touch typist will refer to a person who can type without looking at the keys). Her only previous experience was with a touchtone phone. The next "Old" participant was a male resident of Ann Arbor, MI. He was 67 years old, right handed, wore glasses, was a touch typist, and had previous experience with a QWERTY keyboard and a Cell Phone. The third "Old" participant was a female resident of Ann Arbor, MI. She was 57 years old, right handed, wore glasses, was a touch typist, and also had previous experience with a QWERTY keyboard and a Cell Phone.

The first "Young" participant was a male resident of Saline, MI. He was 35 years old, wore glasses, was right handed, was a touch typist, and had experience with a QWERTY keyboard and a Cell Phone. The Second "Young" participant was a female resident of

Birmingham, MI. She was 21 years old, right handed, was a touch typist, and had experience with a QWERTY keyboard and a Cell Phone. The final "Young" participant was 22 years old and a resident of Ann Arbor, MI. She was right handed, wore contacts, was a touch typist, and also had experience with a QWERTY keyboard and a Cell Phone.

Test Stimuli, Equipment, and Software

Three input devices were tested during the experiment. The devices were a full-size QWERTY keyboard, a personal data assistant (PDA), and a Cell Phone. The QWERTY keyboard was installed into a laptop. The laptop was a Dell Laptitude CPi running on a Pentium II processor with Windows NT. The PDA had a small QWERTY keyboard touch-screen and was activated using a stylus. The PDA was a HP iPaq Pocket PC and rested in a HP H2200 series base. Both screens displayed similar outputs of black letters on a white background, because both were running the Microsoft Word application. The cell phone was an older model and displayed black letters on an illuminated green background. The cell phone, a Samsung SCH-3500, also rested in a charger during the experiment, a Samsung DTC350. All inputs were recorded using a Sony 560x Digital Zoom video camera

The driving task was simulated using a customized Visual Basic.NET computer program, and images were displayed on a 15" Trinitron desktop monitor. The program displayed a small red box within a larger white box. The participant was to keep the cursor in the red box at all times while the boxes moved vertically across the screen. Going outside of the red box target simulated moving outside of the lane in a car. This simulator is used instead of in-vehicle testing because of safety, equipment cost, and experimental control. Studies have also shown that there are good correlations between driving simulators and actual road driving (Reed and Green, 1999). The display of the simulator is shown in Figure 1. The Visual Basic.NET code of this simulator is located in Appendix A.
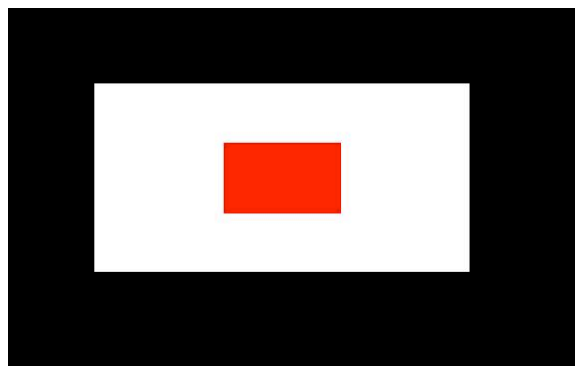

Figure 1: Driving Simulator Program Output

All stimuli and equipment was arranged to be as similar to a car as possible. The participant was asked to adjust their seat distance from the table to be at a comfortable position, as you can do in a vehicle. A diagram of the equipment set-up is located in Figure 2.
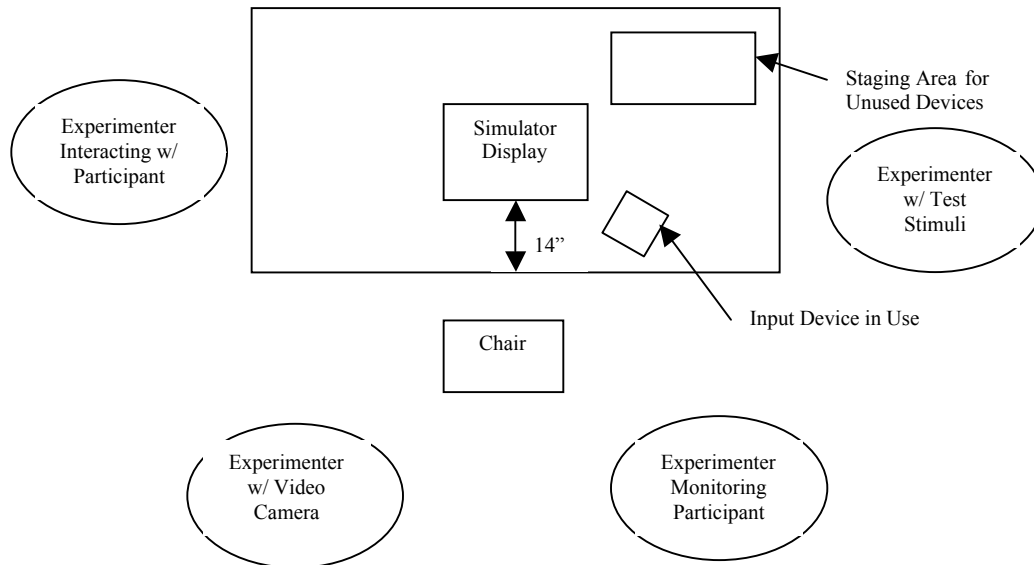

Figure 2: Stimuli and Equipment Layout

Test Activities and Their Sequence

The test participants were seated indoors, in various household chairs (seat height was approximately 16.5 in.) without arm rests. Located directly in front of them on a 29" high table was the monitor used for the simulator and resting on the table was the mouse directly in front of the monitor. To the right of the participants were the different input devices depending on the trial. Before beginning the first block, participants were given the chance to become familiar with the different input devices and the driving simulator. For the input devices, they were all given the same sample inputs (one phrase and one number) on 3x5 note cards. For the PDA and the QWERTY keyboard the phrase was "It is snowing. 2476", and for the Cell Phone the sample number was "876-234-1093". The practice trial for the driving simulator was a 30 second trial run without any input devices.

After the participant felt that they had enough practice with the input devices, the experiment was explained. They were going to be observed using the driving simulator and inputting *new* data into the input devices. These data were, "I am running late. I will arrive at 12:30pm." for the QWERTY keyboard and the PDA, and "594-327-8601" for the Cell Phone. Also, participants were told that "driving is your PRIMARY task," and

to only "finish when the input is as complete as possible". The duration of the testing on each participant depended on the ability of that person. The experiment lasted, on average, between 25 and 30 minuets. The simulator recorded the data of the primary task into a Microsoft Excel Spreadsheet. The data for correct keystrokes was recorded with the video camera and analyzed later. Between each trial the participant was given a brief break while the next input device or lack of input device was set up to their right. If during the trial the participant had a problem with the devices, which they could not remedy without assistance, assistance was given verbally.

Each block of trials was quasi-randomized to minimize the effects of a learning curve. The following order was changed for each participant by moving the last two trials to the beginning and shifting the remaining trials down (N-No Input device, Q-Qwerty keyboard, CP-Cell Phone, and P-PDA): P N Q CP N Q P CP.

RESULTS

The following data represents five of the six test participants. The data for the 85-year-old test participant was not included, because she was not able to complete any of the tasks. She was familiar only with the telephone, and had never used a computer before. The experimenters feel that while this test data was informative, if included, the data would be skewed and not representative of the participants.

Driving

The percentage of time each test participant remained in the target area during the driving task is shown in Figure 3. The data is separated into the two groups of "Young" (16-40) and "Old" (above 40) participants. The "None" column indicates baseline driving task performance without an input device. Overall, the participants were on target the largest percentage of the time when they were driving without using an input device. The participants were least on target using the PDA while driving.
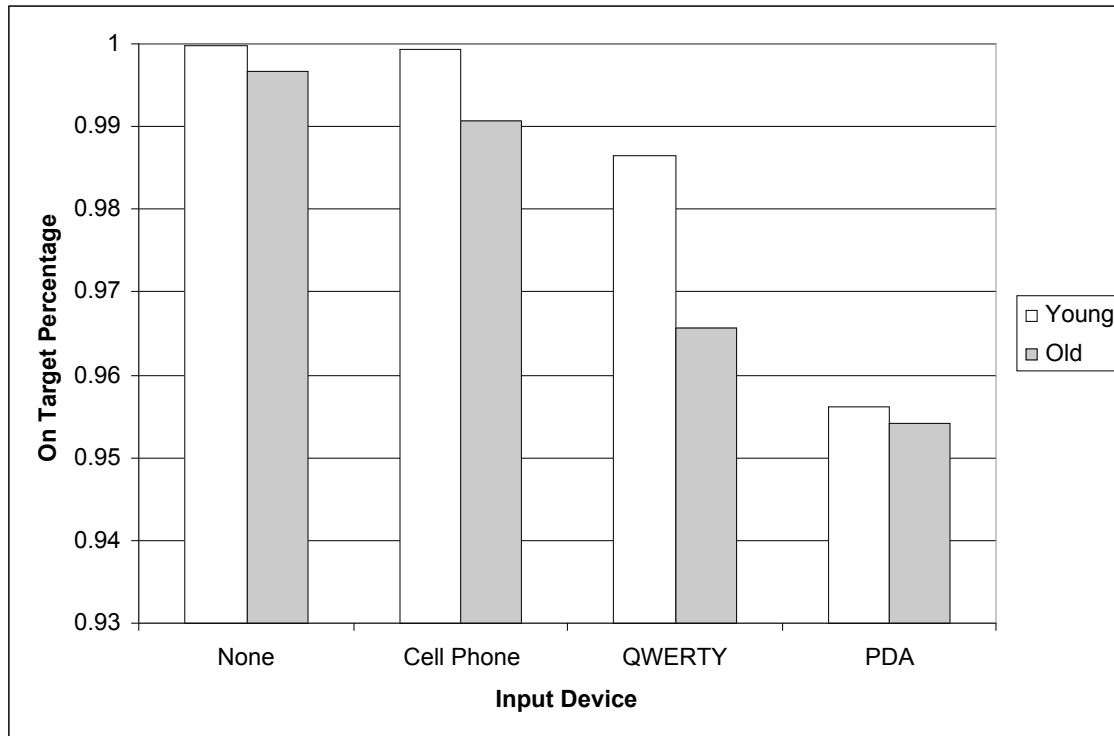
Figure 3: Average on Target Percentages for the Driving Task

For each input device, and lack of input device, the "Young" group was on target a larger percentage of the time. With no input device and with the PDA, the "Young" and "Old" groups performed similarly; there were 0.3% and 0.1% differences respectively. A larger difference, 2.09%, existed between the "Old" and "Young" groups during the QWERTY keyboard entry task. Using the Cell Phone hindered the "Young" group's performance on the driving task very little. There was less than a 0.02% difference between the Cell Phone on target percentage and the baseline on target percentage for the "Young" group.

Table 1 shows the individual performances of the five subjects. While the "Young" group were on target as much or more than the "Old" group for the Cell Phone, QWERTY Keyboard, and no input device, while using the PDA they were the highest, middle, and lowest values. This resulted in the very small difference between the "Young" and "Old" users of the PDA.

Table 1: Average Individual on Target Percentages

Subject Age*	None (%)	Cell Phone (%)	QWERTY (%)	PDA (%)
67	99.36	98.18	97.89	96.00
57	99.97	99.95	95.23	94.83
21	99.97	99.93	99.34	98.89
35	99.97	99.93	99.05	92.26
22	99.97	99.97	97.57	95.67

* The 6th subject, the 85-year-old woman, was on target less than half of the time while not completing any of the tasks.

Devices

Figure 4 shows the time each test participant took to enter the given message into the input device. It is evident that while the QWERTY and PDA had the same task, the participants spent an average of 57 seconds longer completing the PDA task. It is not appropriate to compare the cell phone task to the QWERTY and PDA tasks, because they were not similar in length or content.

Overall, the "Young" group was able to input the data more quickly than the "Old" group. The difference between younger and older participants was 8 seconds for the cell phone, 14 seconds for the QWERY keyboard, and 5 seconds for the PDA.
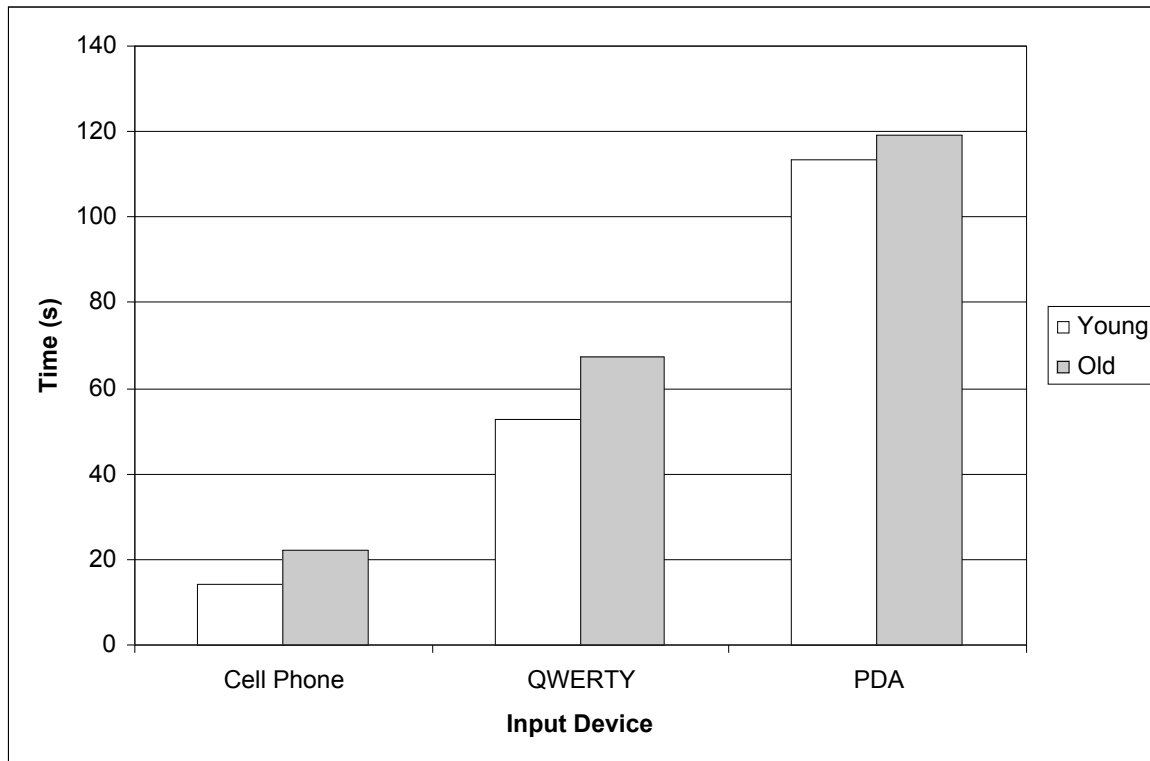
Figure 4: Average Time Spent on Data Input Tasks During Simulation

Table 2 shows the individual averages on each data input task. Overall, all of the younger individuals performed the tasks faster than the older individuals, with the exception of the PDA task.

Table 2: Average Individual Task Times

Subject Age	None (s)	Cell Phone (s)	QWERTY (s)	PDA (s)
67	31.32	25.20	61.96	140.73
57	32.86	18.93	72.74	97.54
21	32.09	14.17	52.37	86.52
35	33.25	13.93	58.65	138.53
22	32.87	14.04	46.89	115.80

Error in Input Devices

Table 3 gives the classifications of the input streams and transcribed text. The test participants made more errors while using the PDA than the QWERTY Keyboard, and were more likely to not fix their errors. While participants made very few errors using the Cell Phone, all of the errors made were corrected.

Table 3: Average Input Stream and Transcribed Text Classifications

	Cell Phone	QWERTY	PDA
IF	0.1	2.6	4.3
C	10	43.6	42.2
F	0.2	5.9	12.6
INF	0	0.3	1.9

IF	Keystrokes in the Input stream, but not in transcribed text, that are not editing keys. (Incorrect Fixed)
C	Correct characters in the transcribed text (Correct)
F	Keystrokes that are editing functions as well as modifier keys (Fixes)
INF	Incorrect characters in the transcribed text. (Incorrect Not Fixed)

These errors were analyzed using statistics described by the new error metrics (Soukreff and MacKensie, 2003). The old KSPC metrics were not used, as they do not separate corrected errors from fixes. Table 4 shows the metrics calculated from the performance data.

Table 4: Metrics Calculated from Input Stream and Transcribed Text Classification Data

	Cell Phone	QWERTY	PDA
Correction Efficiency	0.50	0.44	0.34
Participant Conscientiousness	1.00	0.90	0.69
Utilized Bandwidth	0.97	0.83	0.69
Wasted Bandwidth	0.03	0.17	0.31
Total Error Rate	0.99	6.24	12.81
Not Corrected Error Rate	0.00	0.65	3.93
Corrected Error Rate	0.99	5.59	8.88

Correction Efficiency	IF/F, ease with which the participant performed error corrections
Participant Conscientiousness	IF/(IF+INF), ratio of corrected errors to total errors
Utilized Bandwidth	C/(C+INF+IF+F), amount of useful information transferred
Wasted Bandwidth	1-Utilized Bandwidth, amount of non-useful information transferred.
Total Error Rate	(INF+IF)/(C+INF+IF)*100
Not Corrected Error Rate	INF/(C+INF+IF)*100
Corrected Error Rate	IF/(C+INF+IF)*100

The utilized bandwidth shows the percentage of the time the test participants entered in correct data. The Cell Phone was the most accurately used device, with a 97% utilized bandwidth rate. It is followed by the QWERTY Keyboard at 83% utilized bandwidth, and then the PDA with 69% utilized bandwidth. The correction efficiency, or ease with which the user performed error corrections, was also highest with the Cell Phone, then the QWERTY Keyboard, and lowest with the PDA. They had values of 0.5, 0.44, and 0.34 respectively. Similarly, the rate of corrected errors to total errors was highest with the Cell Phone, then the QWERTY Keyboard, and lowest with the PDA. All Cell Phone errors were corrected, whereas 69% of PDA errors were corrected.

The data suggests that the test participants found the Cell Phone easiest to use and the PDA the hardest to use. Observation of the test subjects also suggests that they found the PDA difficult to use while performing the driving task. Some comments while performing the PDA input task were "I hate it", "It's too small", "This makes me nervous", "It's hard to do capital letters", and "I can't do this!". Comments of this nature were not made about the Cell Phone or the QWERTY keyboard.

CONCLUSION

Data Entry Effects on Driving Task Performance

From the results, one can infer that a data input task into a computing device does have an effect on a driving task. For "Old" subjects, there was a driving task performance decrease in on-target percentage, when it was done in tandem with a data entry task. Data entry into the QWERTY keyboard and PDA resulted in the greatest decrease in driving task performance of 3.10% and 4.25%, respectively. For younger subjects, there was a driving task performance decrease in most of the devices. In younger subjects, the cell phone on target percentage was essentially the same as the on target percentage. Similar to the driving task performance of the older subject, younger subjects had the poorest on target percentage while entering data into the QWERTY keyboard, a difference of 1.3% to the baseline, and a difference of 4.36% for the PDA. Therefore, data entry with a QWERTY keyboard and PDA had a detrimental effect on subject performance for both older and younger subjects. Cell phone data entry, while resulting in a small decrease in on target percentage, did not show the same magnitude in driving task degradation as the QWERTY keyboard and PDA. Younger subjects performed slightly better on all trials, which may be a result of physiological and cognitive advantages over the older subjects.

Data Entry Performance

The results of the data entry task show that the test subjects found the Cell Phone easiest to use while performing the driving simulation. The test subjects entered data into the Cell Phone correctly 97% of the time, compared to 83% and 69% for the QWERTY keyboard and the PDA respectively. The test subjects also corrected 100% of mistakes made on the Cell Phone, compared to 90% and 69% of errors made with the QWERTY

keyboard and the PDA. In addition to making more errors, the subjects also spent an average of 57 seconds longer completing the same task on the PDA than the QWERTY keyboard.

All of the subjects were touch typists, and therefore familiar with the QWERTY keyboard. In addition, none of the subjects were familiar with using a PDA. This could partially explain the difference in the performance metrics. Other factors could include the small size of the PDA keyboard, the use of the stylus, and difficulty in seeing both the keyboard and screen.

The experiment suggests that the Cell Phone is the easiest device for a user to operate while driving. The PDA is the most difficult, with the QWERTY keyboard falling in between.

Experimental Procedure Problems and Recommendations

These results might be challenged because the test conditions, the customized driving simulator, were not completely representative of driving conditions. However, since a simple simulation was used, a real driving situation would lead to more drastic results. Possible sources of error in the experimental procedure were Cell Phone and PDA base stability and usability issues with a PDA. The bases that the cell phone and PDA were mounted on were not completely secure and did move slightly during the trials, which may have resulted in the subjects' key-presses not to be detected by the device. The usability issues with the PDA are in relation to the small point size for the text that appears on the PDA screen. This is a legibility issue that may have induced user errors that would not have occurred had the point size been larger.

It is the opinion of the experimenters' that subsequent research in this area focus on more realistic driving simulators and input devices that are seamlessly integrated into the simulator. Driving simulators that implement lane travel, gas and brake pedals, and other objects moving through the screen, such as car and other roadside objects, will give a driver a more realistic feel for actually driving a car. Simulator control through a steering wheel that properly provides feedback to the user on steering would also be advantageous. Seamlessly integrating the input devices into the simulator may present the device in a way that will be similar to how it would actually be integrated into a car.

REFERENCES

Paelke, G.M. (1993). A Comparison of Route Guidance Destination Entry Methods, Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting,1(1), 569-73.

Reed, M.P. and Green, P.A. (1999). Comparison of Driving Performance On-Road and in a Low-Cost Simulator Using a Concurrent Telephone Dialing Task, Ergonomics, 42(8), 1015-1037.

Soukoreff, R.W. and MacKenzie, I.S. (2003). Metrics for Text Entry Research: An Evaluation of MSD and KSPC, and a New Unified Error Metric, CHI,5(1), 113-20.