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Destination Entry and Retrieval with the Ali-Scout Navigation System

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HUMAN FACTORS

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This research was funded by RCOC and the Federal Highway Administration.

After training, 36 drivers retrieved and entered a total of 20 destinations using an Ali-Scout navigation computer and 10 destinations using a touchscreen simulation while sitting in a vehicle mockup. Retrieval involved keying in part of the destination name, scrolling through a list of names, or some combination of those methods. Entry required keying in the destination's name, longitude, and latitude. Tasks using the real interface were performed under both dusk and nighttime lighting conditions, although the simulated interface was used only at dusk.

Some of the destination entry and retrieval times were unusually long. As a result, medians are more typical times than means (although means were used for ANOVA comparisons). Median retrieval times ranged from 0.4 to 12.0 seconds with an overall median of 6.2. Median entry times ranged from 39.5 to 67.6 seconds with an overall median of 51.5. An additional 30 to 60 seconds were required to look up coordinates in a manual. Mean times for men were 34 percent longer for retrieval and 19 percent longer for entry than mean times for women—both differences were statistically significant. The ratio of mean times for older subjects to mean times for young subjects was 2.8 for retrieval and 2.2 for entry. Performance also varied with context. For retrieval, the lighting condition was not significant but the simulated Ali-Scout took about 75 percent longer than the real Ali-Scout. For entry, times were 22 percent longer at night than at dusk, 37 percent longer using the simulated interface.

Usability problems found involve labeling of keys, the logic for shift key use, and changing fields. Key size and spacing and the lack of feedback were also concerns.

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Destination Entry and Retrieval with the Ali-Scout Navigation System

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Aaron Steinfeld, Daniel Manes, Paul Green, and David Hunter

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The Ali-Scout Keyboard (95% actual size)

1 ISSUES

1. How long does it take to enter and retrieve destinations using the Ali-Scout?
2. How does the Ali-Scout compare with other navigation systems?
3. How does performance vary as a function of driver age and sex, ambient illumination (dusk vs. night), and interface type (real vs. simulated)?
4. What kinds of problems do drivers encounter and how can they be corrected?
5. How accurate are subjects in looking up coordinates in the manual?

2 METHOD

# of Subjects

Age	Men	Women
18 - 30	**6**	**6**
40 - 55	**6**	**6**
> 65	**6**	**6**

# of Trials

Task	Real Ali-Scout		Simulated Ali-Scout
	Dusk	Night	Dusk
Retrieve destination from unit's memory	**5**	**5**	**5**
Enter new destination	**5**	**5**	**5**

Task #1

Retrieve destination from memory

• Retrieve "MAIN THEATER"

Scroll through list ▲ ▼ OR Type characters A1 B2 C3 D4 ... L␣ M· N- O ...

MA_...........

(Subject has begun typing "MAIN")

MAIN THEATER ?

(Once the "I" is typed, the rest of the name appears)

Task #2

Enter new destination into memory

• Enter "KROGERS" with coordinates (0832250W, 422908N)

Type characters ONLY A1 B2 C3 D4 ... L␣ M· N- O ...

KROGERS_......

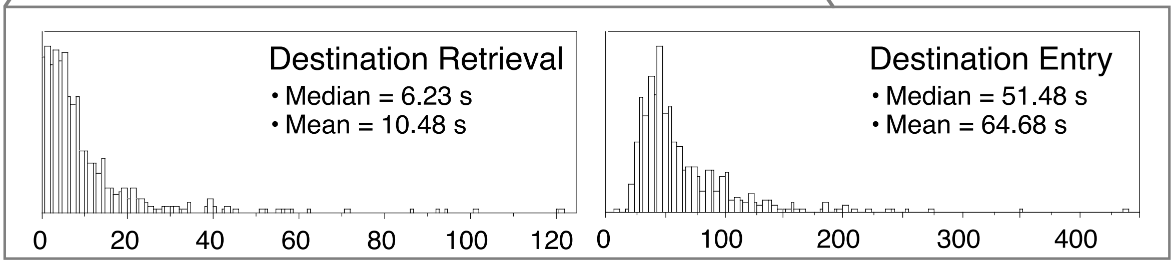
(Subject has typed the destination name)

KROGERS
0832250W 422908N_

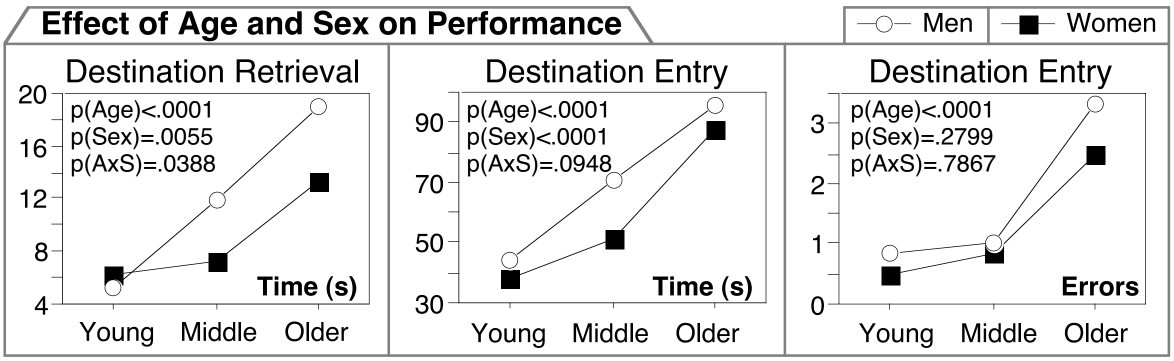
(Subject has typed the coordinates)

3 RESULTS

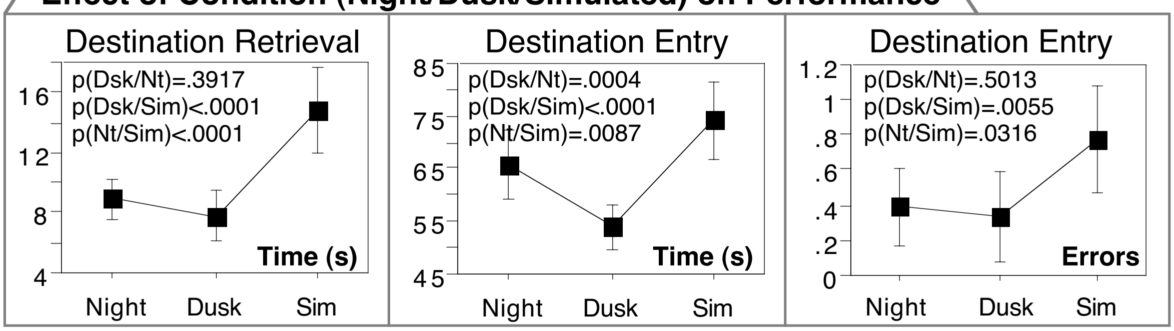
Distribution of trial times for each of the two tasks



Effect of Age and Sex on Performance



Effect of Condition (Night/Dusk/Simulated) on Performance



4 CONCLUSIONS

- Destination entry typically took subjects almost 60 s excluding coordinate lookup time (30 to over 60 s), while retrieval typically took under 10 s.
- Entry and retrieval times were significantly longer for older vs. younger subjects and women vs. men.
- Entry and retrieval times were significantly longer for night-condition vs. dusk-condition trials and simulated-interface vs. real-interface trials.
- The Ali-Scout keys are too small, too close together, and do not provide enough positive feedback when pressed. Some labels should be improved.
- The shifting and spacing functions are confusing.
- The results raise major concerns regarding the usability of any on-road navigation system that relies upon longitude and latitude for destination ID.

PREFACE

This report is one of a series supported by the Road Commission of Oakland County, Michigan, and the Federal Highway Administration, as part of the FAST-TRAC (Faster and Safer Travel through Traffic Routing and Advanced Controls) Project. (See Underwood, 1994: Eby, Streff, Wallace, Kostyniuk, Hopp, and Underwood, 1996; Taylor and Wu, 1995; Kostyniuk, and Eby, 1996 for related research.) This operational field test combines the SCATS (Sydney Coordinated Automatic Traffic Control System) equipment and software, the Autoscope video detection system, and the Ali-Scout (Autofahrer Leit und Information System Scout) dynamic route-guidance system. The goals of this effort are to improve traffic flow and reduce traffic accidents in Oakland County and the surrounding area.

Ali-Scout is a second generation product developed by Siemens, which provides real-time, turn-by-turn guidance to drivers who have units installed in their vehicles. Ali-Scout vehicles communicate with infrared roadside beacons, which send travel times to the traffic control center and receive sequential routing instructions from the center.

If navigation products are to be produced, they must be safe and easy to use. The original program plan called for four human factors studies to examine safety and usability (1) destination entry and retrieval in the laboratory, (2) route following on the road using the Ali-Scout in an instrumented car, (3) getting lost (where drivers are taken off route to see how they and the navigation system recover), and (4) a comparative evaluation of alternative navigation interfaces. Study 4 was canceled first, weakening study 2 (as it was intended to provide baseline data for the Ali-Scout). Subsequently, study 3 was canceled for lack of funding (midway through study 2). During the original definition of the project, the focus was evaluation of the Ali-Scout interface, with comparisons occurring in study 4. However, as the project unfolded, it became clear that a beacon-based system with some of the limitations present in the Ali-Scout interface was not likely to represent future products in the U.S. Further, the cancellation of studies 3 and 4 meant that pilot comparison data had to be conducted in earlier studies, so that the safety of the Ali-Scout interface could be assessed. As a consequence of these changes, emphasis was shifted towards a more general assessment of the desired qualities in navigation interfaces and protocols for assessing them. Such shifts occurred without compromising the intent of the project as it was initially framed.

Driver navigation-related tasks include (1) calibration and set up, (2) telling the system where the driver wants to go (destination designation), and (3) following the guidance instructions. The second and third tasks are more important. The human factors work carried out in the FAST-TRAC project is described in five reports. Matters related to destination designation are covered in this report and a subsequent report on models the prediction of keystroke entry times (Manes, Green, and Hunter, 1996b). Research relating to following route guidance is covered in three reports, one concerning equipment used in the evaluation (Katz, Green, and Fleming, 1995), one concerning turn errors, driving performance, and subjective ratings (Katz, Fleming, Hunter, Green, and Damouth, 1996), and a third concerning driver eye glances (Manes, Green, and Hunter, 1996a, in progress).

This particular report concerns the second task, destination designation. Relevant topics include how drivers determine the coordinates for a new destination, how drivers enter coordinates into the navigation computer, and how they retrieve previously entered destinations. Times and errors for these tasks were collected.

In addition, this report addresses a larger, more fundamental scientific issue—whether a touchscreen simulation of the real product is sufficient for usability assessments. The simulation takes much less time to construct and is easier to modify, facilitating iterative design.

Several individuals and organizations made important contributions to this effort and their contributions are gratefully acknowledged.

Amitaabh Malhotra (formerly of UMTRI)	for programming the Ali-Scout simulation
Patrick Wei, Marie Williams (formerly of UMTRI)	for programming the Ali-Scout simulation
Sara Naylor (formerly of UMTRI)	for testing some initial subjects

Finally, the authors would like to thank Cale Hodder of Toyota for encouraging the authors to include Japanese-style A3 reports (the two-page summary prior to the Preface) in our technical reports.

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INTRODUCTION

Why this topic is of interest

One of the more interesting recent developments for motor vehicles has been the advent of navigation systems. Most of the systems planned or in production identify the location of a vehicle on an electronic map and provide both visual and voice directions to driver-selected destinations. In some systems, current traffic conditions are considered in route calculations. Navigation systems are very popular in Japan (Treece, 1996) and may see broad market penetration in the U.S.

Such systems can reduce wasted travel, saving drivers time and fuel, and provide for operational efficiency by optimizing use of the road network. By decreasing driving under uncertain conditions and eliminating the use of paper maps while driving, accidents may be reduced. Finally, these systems will offer comfort and convenience to drivers. However, such positive outcomes are predicated upon the assumption that these systems are safe and easy to use.

There are two primary driver tasks in using these products: (1) entering and retrieving stored destinations, and (2) following the directions given by these systems (route guidance). Secondary tasks include setting and calibrating the system. Route following deserves the most attention because it occurs while the vehicle is in motion. Route following is covered in other reports in this project (Katz, Green, and Fleming, 1995; Katz, Fleming, Hunter, Green, and Damouth, 1996). However, destination designation also must be considered. Generally, destination designation is assumed to be performed while the vehicle is stopped or parked. However, in many circumstances, such as driving on an expressway, stopping may be difficult, so destination designation while in motion may be less risky. There is great concern as to what a driver can do while in motion (Zwahlen and DeBald, 1986; Zwahlen, Adams, and DeBald, 1988).

Previous research

Several studies in the literature have examined the entry of location names, street addresses, and coordinates, a focus of this experiment. The review provided here is extremely detailed. Those details concern subject samples, tasks, and test protocols, all necessary to make comparisons of the relative ease of use of alternative interfaces.

One method to enter navigation information is to use a telephone keypad (Figure 1), a topic addressed by Marics (1990). Keypads require a minimal of instrument panel space, a premium in contemporary vehicles. Marics examined behavior for entering names including q, z, apostrophe, and hyphen, characters not present on a keypad but present in names. Twenty subjects were given a stack of index cards with 20 names on them and did what they thought was best to enter the names. Table 1 summarizes the results. Except for entering an apostrophe (which subjects omitted), no single method was preferred by more than half of the subjects. This makes selecting a stereotype difficult. For q and z, the most commonly selected key was the asterisk, selected by about 1/3 of the subjects.

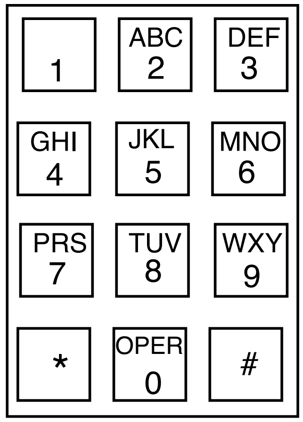


Figure 1. Phone Keypad

Table 1. Choices of Keys to Use (in percent)

	alpha keys	other keys	omitted	mixed strategy
q and z	25	40	5	30
apostrophe		15	80	5
hyphen		35	35	30

In related work, Detweiler (1990) examined alternative methods for entering text using a phone keypad. Five methods were examined as described in Table 2 and Figure 2.

Table 2. Description of Methods Used by Detweiler (1990)

Method	Description (to enter K)
Repeat key	press 5 twice, once to indicate which group of three letters, a second time because K is the second of 3 letters (JKL)
Same-row	press 5 twice, once to select the JKL key, a second time because 5 is the second key on the same row (GHI/JKL/MNO)
Top-row	press 5 to select the JKL key, then 2 (on the top row) because K is the second of 3 letters (JKL)
Modal-position	press "OPER" to select the second position (it is the second key in on the bottom row), then 5 because K (JKL) is on that key. This method resembles the same-row and top-row methods, except that it uses the bottom row and the keys are reversed.
Modified-modal	press 5 to select the JKL key, then * (the first special character) to select K; to select J, press only 5; to select L, press 5 to select the JKL key, then # (the second special character) to select L

Note: The general approach is the first keystroke selects the key, subsequent keystrokes indicate the specific character on the key.

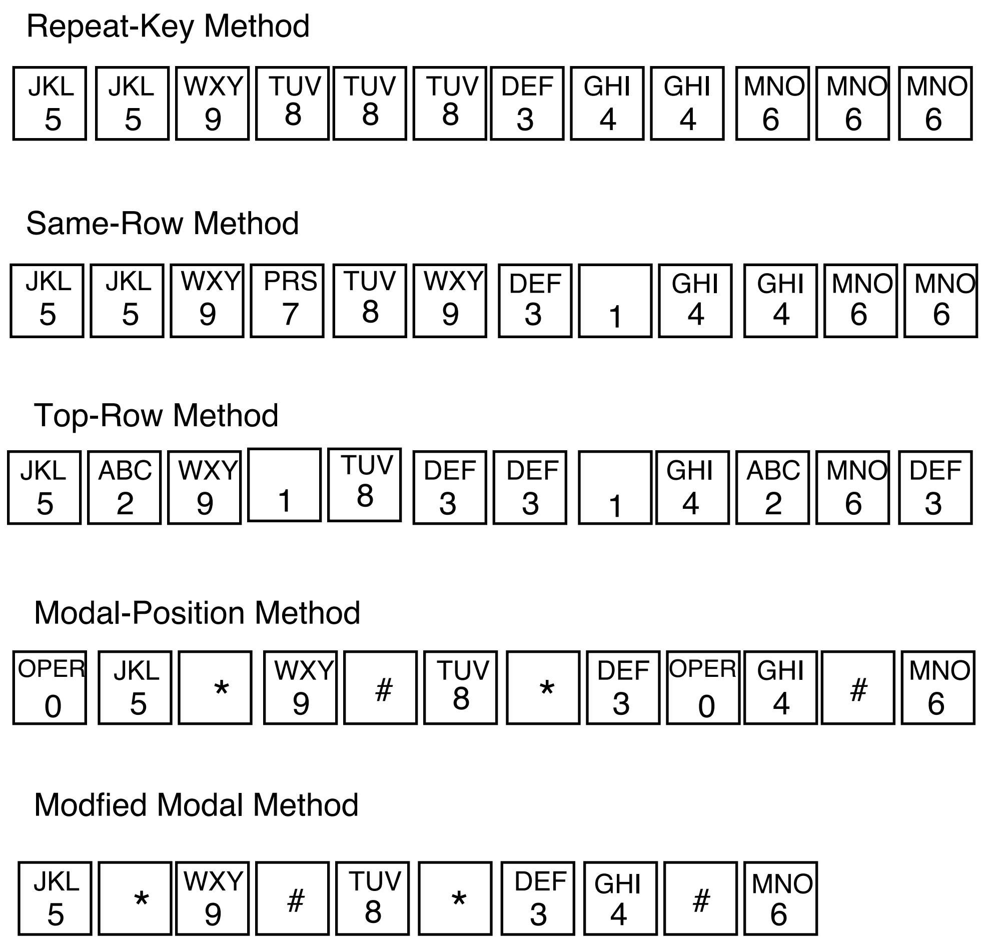


Figure 2. Key Sequences to Enter "KWV DHO" Using Various Methods.

Fifty adults were timed as they entered 24 six-letter strings. Table 3 shows the results. There were no statistically significant differences in the entry times, though the error differences were significant. In part, this was because the repeat key method minimized finger movements and the probability of striking the wrong key. Interestingly, GOMS model (Card, Moran, and Newell, 1983) predictions of entry times (using the Slowman assumption) matched the actual times fairly well, except that the rank orders of the Modified-Modal and Top-Row methods were reversed. This provides an indication that GOMS models could be useful for keypad entry tasks.

Table 3. Entry Times and Errors for Various Methods

Method	% Errors	Entry Time (s)	GOMS (s)
Repeat key	6.7	12.38	11.96
Modified-modal	17.1	12.50	13.72
Top-row	8.0	13.50	13.50
Same-row	10.5	14.18	13.78
Modal-position	13.0	14.81	14.58

Several studies have reported times for destination entry and other tasks examined during the development of interfaces for operational field tests. As part of the ADVANCE project, Loring and Wiklund (1990a) describe and evaluate three prototypes for keypads allowing destination and other data entry. There were 12 subjects ranging in age from 19 to 68 (mean=41). Figures 3, 4, and 5 show the designs evaluated. Twelve subjects performed sample tasks using low fidelity SuperCard prototypes in a laboratory. Table 4 shows the mean times to complete tasks, though the units are not given in the report. The times are probably in minutes.

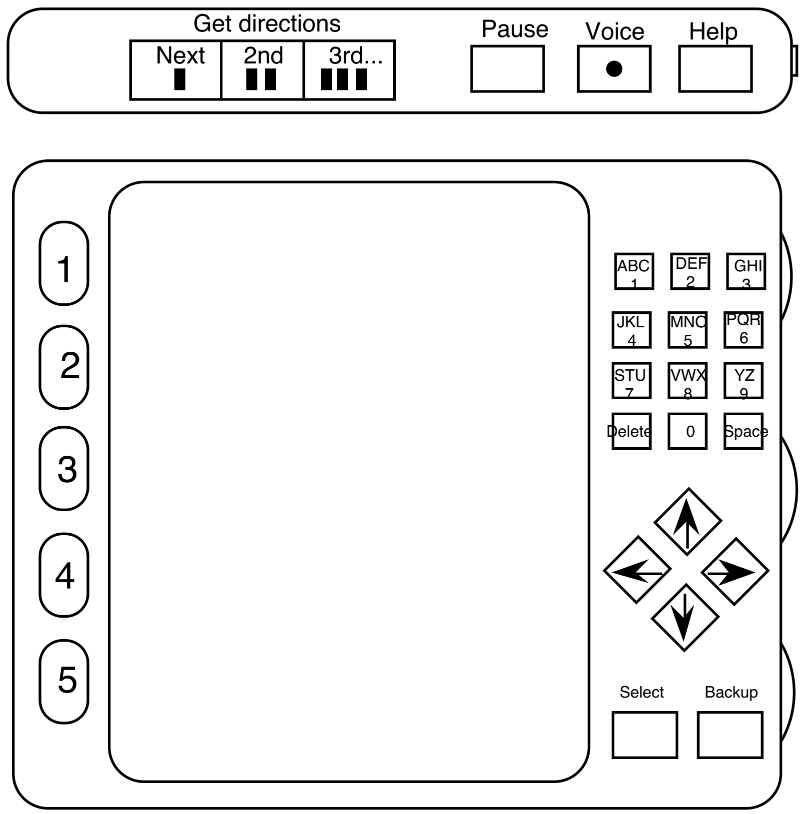


Figure 3. Design A - Soft Keys and Dedicated Keys
(12 dedicated keys (including arrow cursor keys), 12-key alphanumeric pad,
5 soft keys, and a menu hierarchy with many layers)

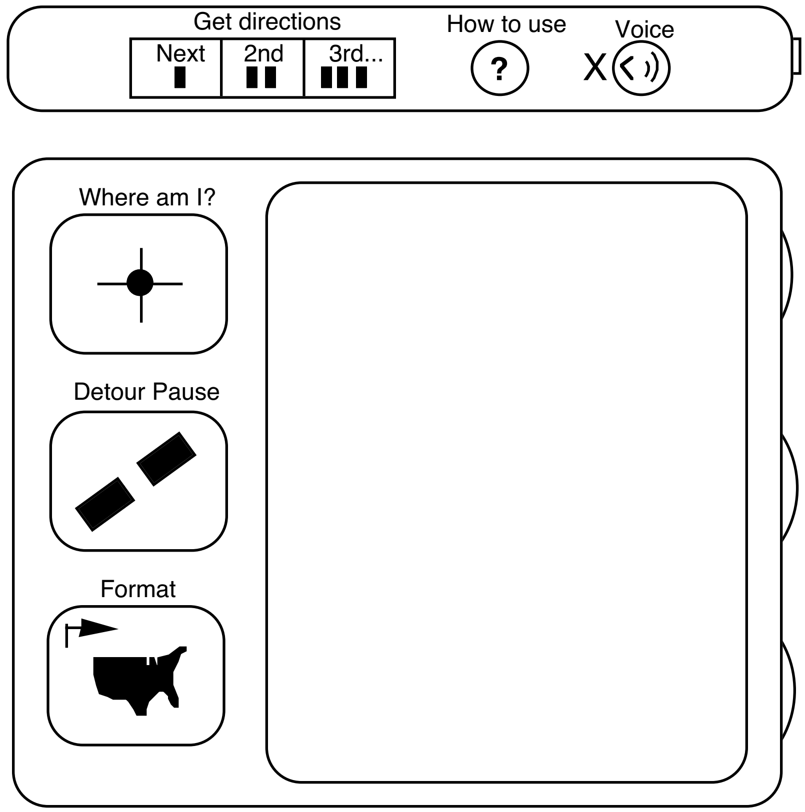


Figure 4. Design B - Touchscreen and Dedicated Keys
(8 dedicated keys, a touchscreen menu hierarchy with many layers, and separate mini Qwerty keyboard)

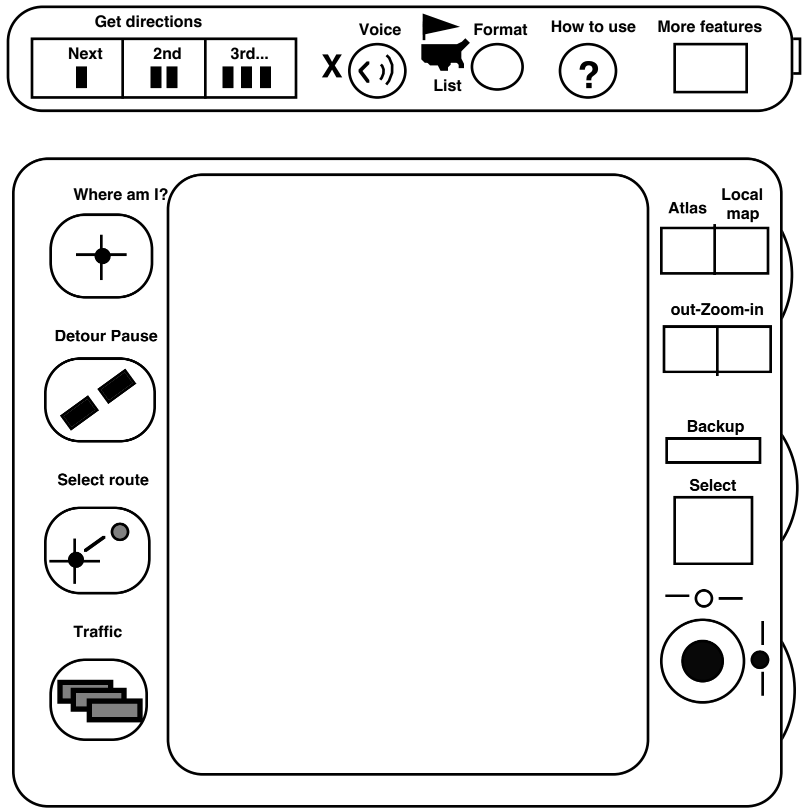


Figure 5. Design C - Dedicated Keys
(18 dedicated keys (including a cursor control knob), a menu hierarchy with fewer layers, and separate mini Qwerty keyboard)

Table 4. Task Times form Loring and Wiklund (1990a)

Task	A: soft keys & dedicated keys	B: touchscreen & dedicated keys	C: dedicated keys
Determine present location on a map	0.911	2.924	1.125
Get info on Symphony Hall from list of public places	3.550	3.032	4.352
View traffic conditions near present location	2.725	3.461	1.571
Plan a route to the Grand Hotel in San Francisco	3.576	2.974	3.076

In structured interviews, subjects said that design B appeared easiest to use initially, proved easiest to use after one week, and outranked the other two as the design they preferred to have in their own cars. They said that design C was the most difficult-appearing initially and the hardest to use during the experiment.

Loring and Wiklund (1990b) had 9 subjects (varying in experience but of unknown age) perform a variety of tasks with prototype 2 of the ADVANCE interface (an illustration of the interface did not appear in their report). Appendix A shows the adjusted mean times from that baseline evaluation. The range of task times is quite large, with one task taking over three minutes.

Coleman, Loring, and Wiklund (1991a,b) had 20 subjects enter alphabetic strings (e.g., street names), numeric strings (e.g., long distance phone numbers), and alphanumeric strings (street addresses) on 5-inch diagonal touchscreens. Keyboard styles explored included Qwerty, Qwerty-matrix, and alphabetic. The two Qwerty keyboards were faster (0.55 seconds per keystroke) than the alphabetic keyboard (0.73 seconds per keystroke). Differences in errors were not statistically significant. This suggests that where touchscreen resolution is available, keys should be in a Qwerty format.

As part of the TravTek project, Dingus, Hulse, Krage, Szczublewski, and Berry (1991) had subjects perform seven nondriving tasks with a navigation system interface. Several of them involved entry or retrieval of destinations (select an unfamiliar address—mean 130 seconds; select a stored destination—mean 50 seconds; store a destination and route—mean 160 seconds; and use a yellow page feature for a destination—mean 90 seconds). The error patterns were parallel to the task times. Both sets of data were markedly affected by age (for example, the mean times for older subjects were almost double that of younger subjects). Table 5 shows the full set of times for the sake of completeness.

Table 5. Task Completion Times from
Dingus, Hulse, Krage, Szczublewski, and Berry (1991)

Task	Time (s)
Enter an unfamiliar destination	130
Retrieve stored destination	50
Determine areas where congestion is present	240
Add destination and route to list of those stored	160
Use yellow pages feature to select a business	100
Set voice messaging option	40
Summon emergency service	40

One of the constraints of designing navigation interfaces is the limited space available on the instrument panel. To address the issue of input-device real-estate requirements, Sears, Revis, Swatski, Crittenden and Shneiderman (1993) had 24 subjects type on a touchscreen Qwerty keyboard that registered input using a lift-off strategy (and presented a tone). The four key sizes were 0.57, 0.76, 1.14, and 2.27 centimeters per side, associated with keyboards 6.8, 9.0, 13.2, and 24.6 centimeters wide (from the Q to P keys). For each keyboard, data was collected for a novice phase (one practice string and three test strings) and an experienced phase (after 30 minutes of practice). Mean entry rates ranged from 1.29 to 0.61 characters/second for novices (from smallest to largest keys) and 0.57 to 0.37 for experienced subjects. For both groups of subjects, the relationship between entry time and key size was linear.

More to the point of this project, Paelke (1993) (see also Paelke and Green, 1993) describes an experiment comparing four different interfaces for destination entry.

These interfaces were designed to capture the variety of entry themes present in contemporary products. Sixteen drivers (8 young, 8 old) served as subjects. Interfaces were presented on a touchscreen CRT, of which a 5-inch (12.7 centimeters) diagonal section, the size of a typical navigation interface, was visible.

For the double-press method, a matrix of 10 touch areas appeared, with up to four characters per area (EFGH in Figure 6). Touching one of the multicharacter buttons caused touch areas to appear, one for each character. Touching the desired character (E, F, G, or H) caused it to be selected. This design was similar to that used in the TravTek interface, a field test conducted in Orlando, Florida. This design overcame limitations of the resolution of the touch interface.

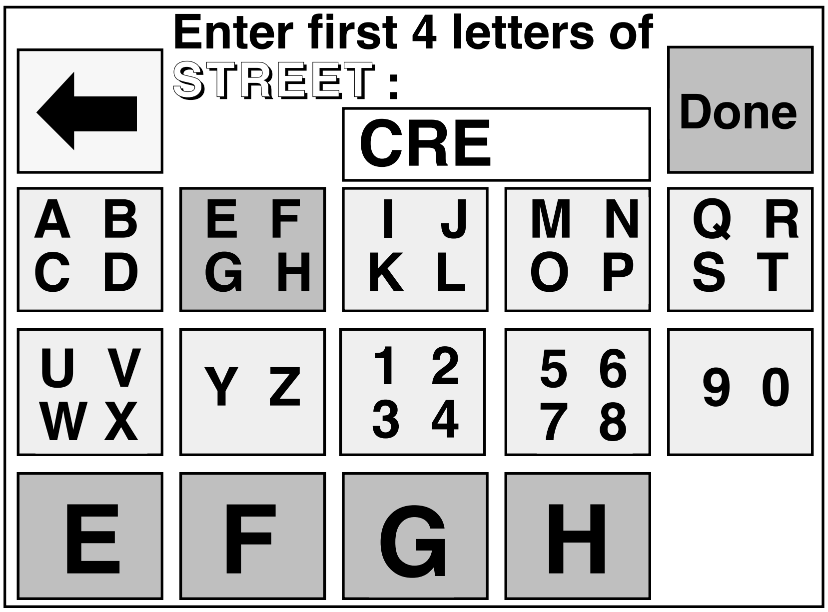


Figure 6. "Double-press" interface design

In the Qwerty interface, the arrangement of touch areas resembled that of a typical keyboard. While the arrangement was familiar to typists, the keys were smaller than is typical for keyboards. The arrangement was used for the ADVANCE interface examined in field trials in Chicago.

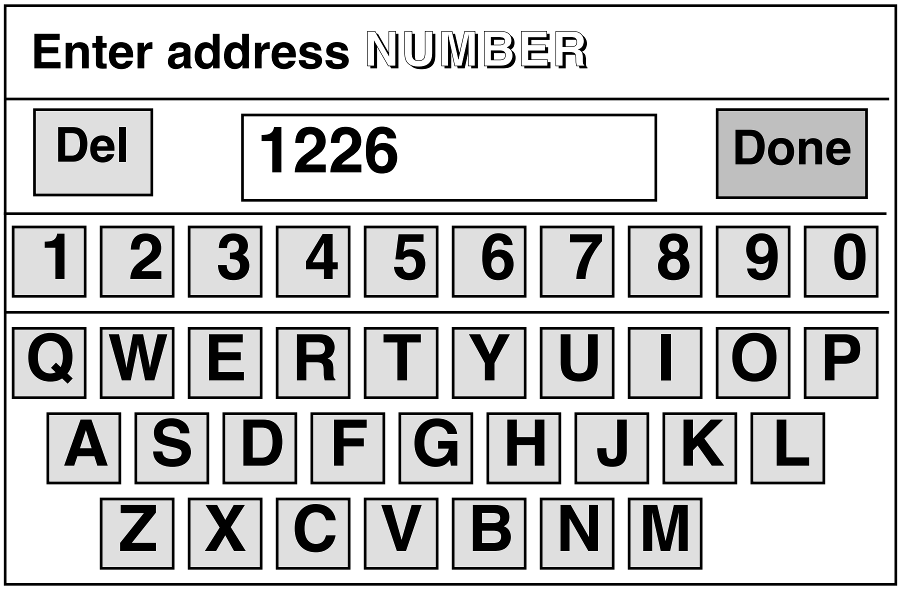


Figure 7. Qwerty-style keypad interface design

In the phone pad interface, subjects were shown numeric keys on which multiple letters appeared. (See Figure 8.) So, for example, to enter "ELUM," subjects typed 3586. Because multiple text entries could match any string of digits (e.g., FLUN would also match), a scrollable list of alternatives was then presented for final selection. (See Figure 9.)

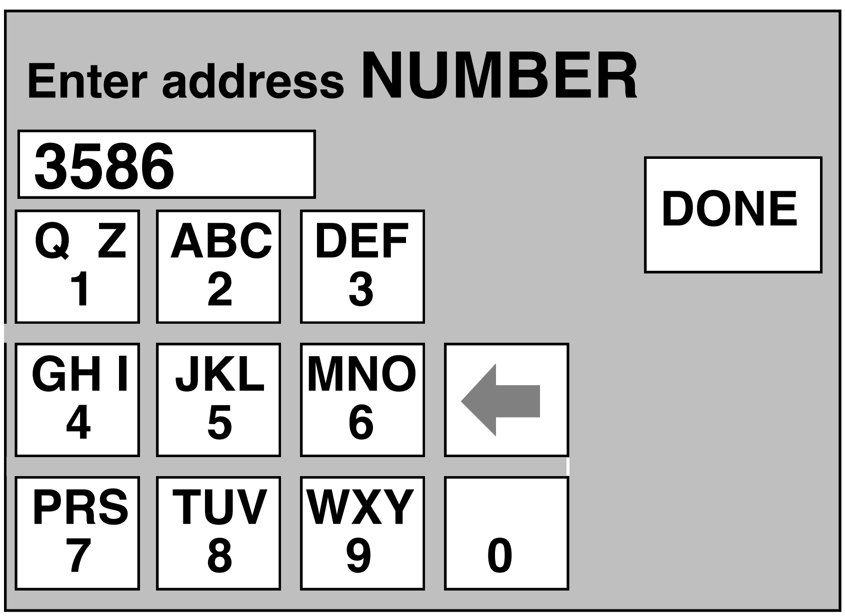


Figure 8. Phone-style keypad entry method

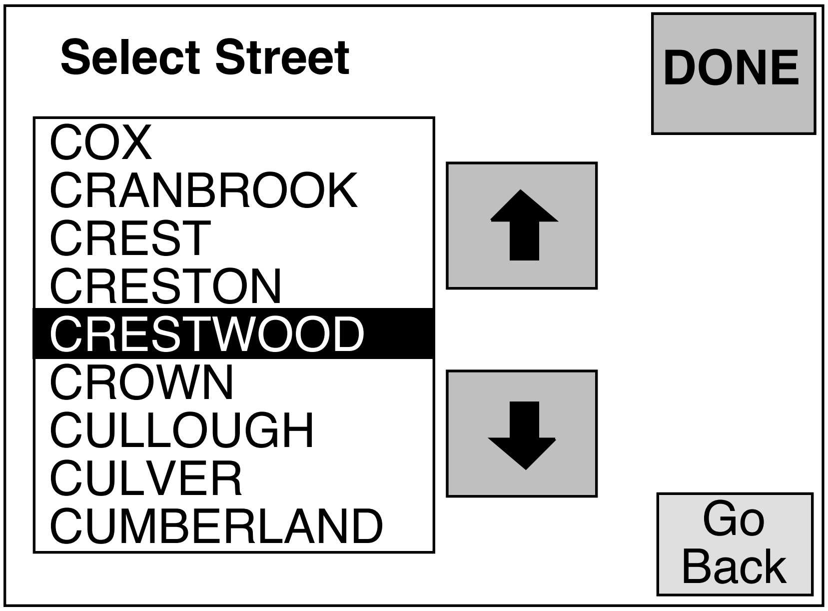


Figure 9. Selection screen for double-press and Qwerty name selection

The fourth interface style resembled that in the Zexel navigation system, currently found in the Pathmaster sold by Rockwell (Figure 10). To move the scrolling list forward or backward one character in the alphabet, the A and Z keys are pressed. To move forward or backward one entry in the list, the up and down arrows are used.

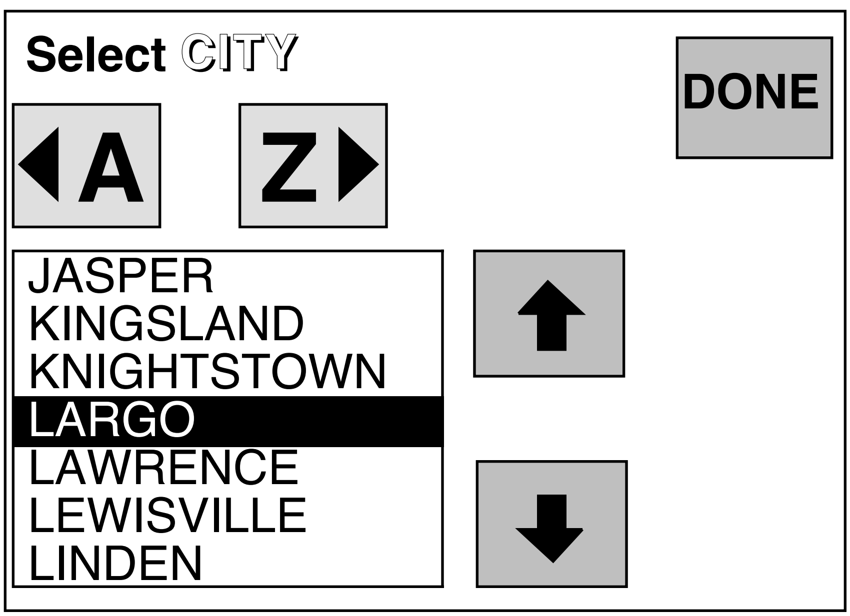


Figure 10. Scrolling List Interface Design

Eight destinations were entered for each interface design while parked or while driving a very simple simulator. Destination entry times were 43 seconds for the phonepad, 44 seconds for the Qwerty, 55 seconds for the scrolling list, and 76 seconds for the double-press interface. The overall differences in entry methods were highly significant. Older drivers' entry times were 21 percent longer than those of younger drivers. Having people drive the simulator while entering destinations increased the entry times by 28 percent over the baseline (parked) condition. The standard deviation of lane position increased from 6 inches (baseline) to about 11 inches (dual task). The order of the error data (from best to worst) was identical to that of the entry times. Also identical was the order of the GOMS model predictions of performance. Thus, this experiment demonstrated the utility of GOMS estimates for predicting driver performance with realistic navigation interfaces.

Eby, Streff, Wallace, Kostyniuk, Hopp, and Underwood (1996) described a pilot test concerning user perceptions and use of the Ali-Scout interface. A total of 62 drivers had Ali-Scout units installed in their vehicles for two months. These were mostly professionals at General Motors and Chrysler (almost 60 percent had a household income of $100,000 or more). Of them, 45 completed the first survey (one week after participation) and 36 completed the second (two months after participation). Drivers also completed a daily log of their trips.

With regard to entering destinations, the following was learned. In terms of frequency of use, the rank order of destination designation methods was map method (look up the coordinates on a map), current location (indicate the current location is the destination), points of interest (find the coordinates in a list of places), and address range (find the coordinates in a list of street addresses). A more detailed description of these four methods appears in the Test Plan section of this report. Subjects reported that the current location and points of interest methods were easy to use and that the address ranges and map methods were difficult to use. Both surveys indicated the same results.

About 70 percent of the trips involved a destination already in memory. Table 6 lists the frequencies. Subjects thought this feature was easy to use; about one-half indicated that it was "very easy to use."

Table 6. Frequency of destinations Reported in Driver Logs.

Destination	Frequency (%)	Destination	Frequency (%)
Home	41	Church, etc.	2
Work	22	Medical	1
Shopping	10	Entertainment (e.g., movie)	<1
School	7	Child car	<1
Friend's/Relative's home	4	Motel/Hotel	<1
Restaurant/Bar	2	Other	7
Recreation (e.g., golf course)	2		

Some 53 percent of the subjects indicated the keyboard was easy to learn, while 29 percent thought it was difficult to learn. The remaining 22 percent were undecided or did not respond. In terms of ease of use, 49 percent felt it was easy to use, 38 percent felt is was difficult, and 11 percent felt it was neither easy nor difficult. In terms of reliability, 25 percent thought the keyboard did not function properly. Finally, with regard to their overall impression, about 47 percent disliked the keyboard to some degree. This is not a desirable outcome.

Several of the experiments described in this section used simulations of interfaces to predict performance with real interfaces. To examine the validity of that approach, Archer and Yuan (1995) presented four pairs of interfaces to 16 MBA students. The interface examined various ways to enter text into a telephone system. Two interfaces involved a 12 key phonepad supplemented with four additional keys (alphabet, number, clear display, send message and clear). In the multipress implementation, the character key is pressed to select that mode, then the key with the character on it is pressed multiple times to select that character. (The 2/ABC key is pressed three times to select C.) This is similar, but not identical to the repeat key method examined by Detweiler (1990). In the character pick interface, pressing the alphabet key and then a key, for example 2/ABC, cause the triple A, B, C to appear on a display. To select C, the 3/DEF key is pressed because it is the third key. This is similar to the top-row method examined by Detweiler (1990). Also examined were a Qwerty keyboard and a touchscreen simulation of one. All simulations were implemented in Toolbook.

Three tasks were completed: (1) ordering tickets using a data base with menus, (2) entering credit card information to pay for the tickets, and (3) entering an address to which the tickets were to be sent. Subjects then rated the pair of interfaces they used on 10 characteristics.

Table 7 shows the entry times and errors. The touchscreen simulation took 14 percent longer and led to 50 percent more errors than the real interface. However, the actual number of characters entered was only 3 percent greater. The time differences were not statistically significant, leading the authors to claim that the use of simulations is an appropriate substitute for real interfaces in usability tests.

Table 7. Entry Times and Errors Reported by Archer and Yuan

Interface	Corrected Task Time (s)	Errors (%)
Multipress	487	21.3
Character pick	361	7.2
Touchscreen keyboard	220	9.3
Real keyboard	193	6.2

Not only are evaluations of real interfaces important, but so too are evaluations that develop a basis for predicting user performance. As an example, Hoffman, Tsang, and Mu (1995) described two experiments to predict movement times between keys as a function of key size and spacing. In the first experiment, 10 young men served as subjects. The square keys were 5, 10, and 15 millimeters on each side separated by either 1, 5,10, 15, or 20 millimeter gaps. Reciprocal movements were between a starting key and a second key 1 to 5 keys to the right. The performance measure was the number of key taps in 10 seconds. The best fitting equation for movement time (milliseconds), accounting for 95 percent of the variance, was:

$$MT = 187 + 6.68\ (ID - 1.18)^2 + 13.3(Nkey)$$

ID = Index of Difficulty = 2 * movement distance/target width
Nkey = number of keys to the second key
target width = key width + finger width, where interkey width > finger width
or
= 2 * (center to center distance) - key width - finger width

To examine the effect of marking the keys, the target key was indicated with a black spot. An additional 10 young men served as subjects. Only combinations of 1, 3, or 5 keys were examined. Key sizes and spacings remained the same. For the full data set, 95 percent of the variance in movement time was accounted for by the following expression:

$$MT = 169 + 3.45(ID)^2 + 10(Nkey)$$

In summary, the key studies (Paelke, Coleman, Detweiler, etc.) suggest the following.

1. If a touchscreen keyboard is to be used, it should follow a Qwerty format, though the exact spacing (standard Qwerty, Qwerty matrix) does not matter.

2. For reduced resolution touchscreens, the rank order of interface designs (from best to worst) is phonepad, Qwerty, scrolling list (Zexel), and double press (TravTek).

3. The rank order of actual keying times and GOMS-predicted keying times are the same for four representative interfaces. However, prediction errors of actual performance times can be considerable.

4. Except for omitting apostrophes, there are no majority stereotypes for how drivers deal with unusual names (those with q, z, or hyphens in them) when using phone keypads for entry.

5. Of the methods for using phone keypads for name entry, there is no single method whose performance is clearly superior to others, though the repeat key method is best.

6. In the Eby, Streff, Wallace, Kostyniuk, Hopp, and Underwood (1996) study of the Ali-Scout interface, more subjects rated the interface as easy to use than difficult to use, but the responses were not overwhelmingly positive. Almost half of the subjects disliked the keyboard to some degree.

7. Touchscreen simulations of user interfaces may offer reasonable performance predictions.

8. Movement times for alternative keyboard configurations can be predicted using equations based on Fitts Law.

For other information on design guidance, see Green, Levison, Paelke, and Serafin (1993).

Research issues explored

Thus, while the literature suggests that GOMS predictions may be useful in evaluating the Ali-Scout keyboard and that the basic Qwerty configuration is preferable, the usability of the keyboard cannot be determined from the literature. For this reason, an experiment was conducted to determine if the interface was easy to use by drivers of all ages for destination entry and retrieval, and to identify usability problems. This experiment was carried out in parallel with the survey effort described in Eby, Streff, Wallace, Kostyniuk, Hopp, and Underwood (1996). Specifically, the following questions were addressed.

1. What are typical entry and retrieval times (and error rates) for destinations?

2. How does the Ali-Scout entry and retrieval times compare with those for other systems described in the literature?

3. Does performance change with practice?

4. How does performance (time and errors) vary as a function of driver age and sex?

5. What subject factors other than age and sex influence performance in this experiment?

6. How do time and errors vary as a function of ambient illumination?

7. Are the times and errors the same for real and simulated interfaces?

8. What kinds of problems do drivers of all ages encounter (and how can they be corrected)?

9. How close are GOMS predictions of times to values from real and simulated interfaces?

10. How accurate are subjects in looking up coordinates in the manual?

The rationale for these questions is shown in Table 8:

Table 8. Rationale for the Issues Examined

Issue	Rationale/Deeper Issue
Typical times and errors	To make comparisons (both with other systems and to gauge improvements), baseline data are needed.
Comparison with other systems	How should a navigation system be designed to be safe and easy to use?
Effects of age, sex, and other subject factors	Will any group have particular problems? This influences who should be subjects in future usability tests.
Ambient illumination	Are there lighting problems? Does lighting in tests matter? Should multiple lighting conditions be examined in future tests?
Real vs. simulated interfaces	Can simulated prototypes, popular in preliminary tests, predict real system usability? This could reduce the cost of usability tests needed during development since only a simulation is needed.
Usability problems	How can the Ali-Scout be improved?
GOMS predictions vs. real and simulated interfaces	Can predictions be substituted for usability tests where age is an issue (not examined by Detweiler and touched upon by Paelke)? This could reduce the number of costly usability tests needed during development.
Looking up coordinates	Ali-Scout is unique in that it uses longitude and latitude. Does that create problems?

To speed dissemination of the results, findings concerning the GOMS predictions are covered in a subsequent report (Manes, Green, and Hunter, 1996b).

TEST PLAN

Test participants

There were 36 subjects in the experiment: 12 young (18-30), 12 middle-aged (40-55), 12 older (over 65). The young and old groups represent the population extremes. The middle group comprises the most likely buyers. Within each age group there was an equal number of men and women. All subjects were licensed drivers (1,000 to 40,000 miles per year, mean of 13,000). The sample was well educated. All but three had at least some college and 13 had at least one college degree. Vision ranged from 20/13 to 20/22 (corrected) in the young group, 20/13 to 20/40 in the middle aged group, and 20/15 to 20/40 in the older group. Only one subject had previous experience with a navigation system, and 20 of the 36 had used a touchscreen. Computer use was moderate on average (3.4 where 3=a few times a month, 4=a few times a week) and subjects reported they were moderately comfortable typing (mean 3.9, 4=moderately comfortable). Subjects were midway between very comfortable and moderately comfortable in using maps.

The subjects included both those who have served in previous UMTRI studies (none of which concerned destination entry) and new recruits. New recruits were obtained through friends of the experimenters and other subjects.

Test materials and equipment

Ali-Scout interface

This experiment incorporated a real Siemens Ali-Scout Display Unit as well as a simulated version. Figures 11 and 12 show frames grabbed from video recordings of device use. Notice the similarity of the appearance of the two implementations. These recordings were later used to identify subject actions and times (for the real unit only).

Figure 11. The Real Display Unit

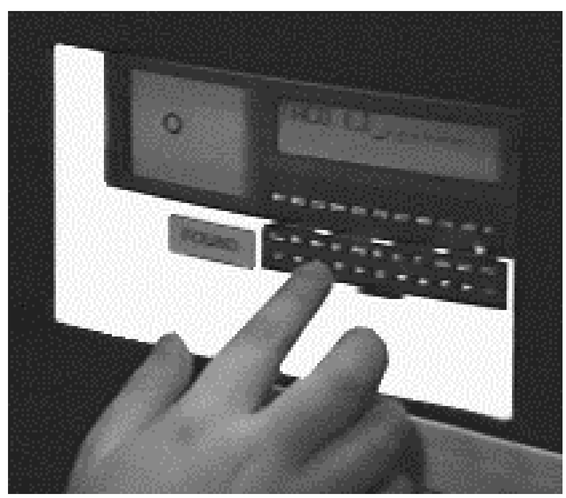


Figure 12. The Simulated Display Unit

The Ali-Scout interface consists of four elements, an LCD guidance screen on the left of the unit face, a text window for destination names, coordinates, entry information, front panel selection keys, and a fold-out alphanumeric keypad. Figures 13 and 14, actually taken from the simulation, show the Display Unit closed and open. These figures are full size on an 8.5 inch x 11 inch page. (Both the real and simulated Display Units were 7 1/4 inches x 2 1/4 inches (18.4 centimeters x 5.7 centimeters.) The "found" button was not part of the device but was added to assist in timing use performance. The button was fabricated out of wood and attached to the zero key of a Kensington NoteBook KeyPad mounted just behind the Ali-Scout unit.

Figure 13. The Simulated Display Unit with the Door Up

Figure 14. The Simulated Display Unit with the Door Down

The simulated Display Unit was created in SuperCard 1.7.1. The program recorded the times for button presses and, opening and closing the door. The simulated image of a Display Unit was presented on a ELO Touch Systems Intellitouch monitor (model E284A-1345) mounted on an Apple Macintosh model M1212 13-inch (33 centimeter) CRT positioned in the center console of the dashboard. The frame of the display is visible in Figure 15. The size and appearance of all elements of the simulated display were identical to the real interface except that there was no tactile feedback when a key was pressed, something that created major problems for subjects in pilot tests. As a consequence, in the simulation a tone was presented each time a key was pressed. This seems to have solved the problem.

The real Display Unit was mounted on a flexible stalk that was positioned by the experimenter placing the display face 3-1/2 inches (8.9 centimeters) in front of the touchscreen when in use. A holder for the address cards was mounted just below the display. Dimensions for the location of both displays and the card holder appear in Appendix B.

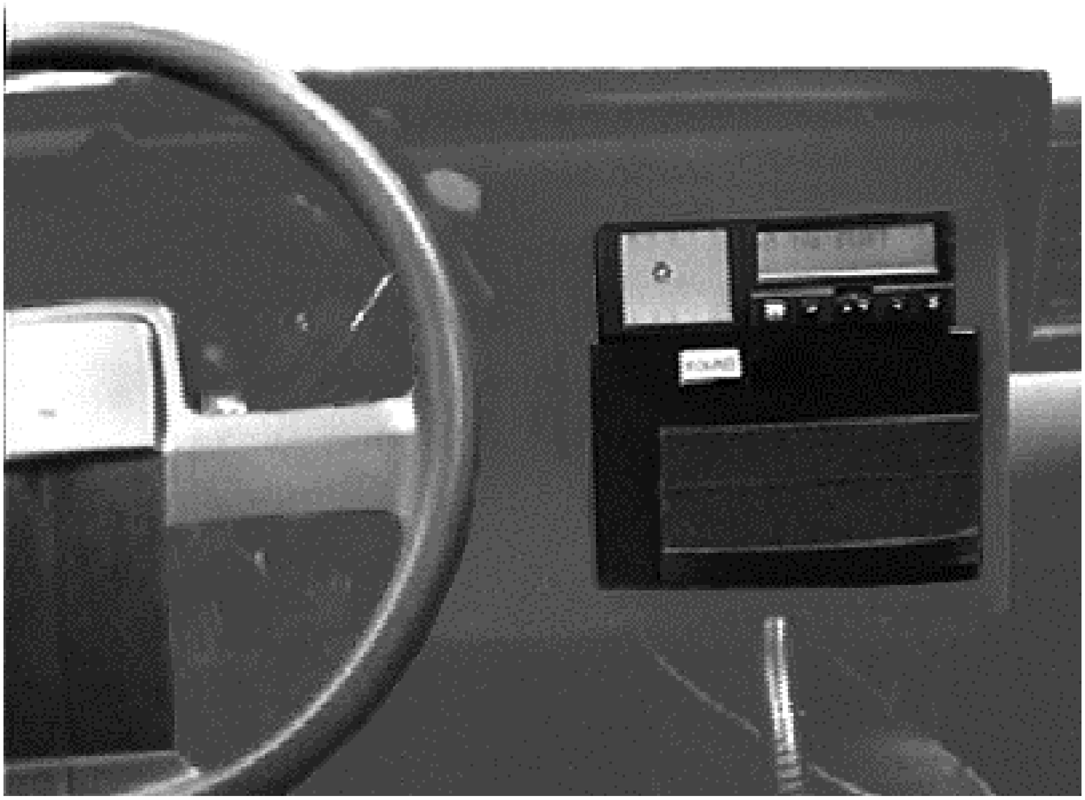


Figure 15. Location of Displays

The Ali-Scout unit can store up to 80 destinations. To retrieve a destination, subjects could use one of three strategies: type in the name of the destination, which appeared when the characters entered uniquely matched the beginning of that name ("Character Search"); scroll through the list of names to the entry desired ("Scroll Search"); or type the first character or two and then scroll the rest of the way ("Hybrid Method").

Table 9 shows the keystrokes necessary to obtain SEARS as a destination. Assuming the subject had not memorized the data base (there were 21 locations in the main list), the minimum character strokes required using either method would be 4. The first down arrow is required to enter the scrolling function.

Table 9. Methods for Character Searching

Location List
AT THE START
...
SAKURA BANK
SEAFOOD BAY
SEARS
VANDENBURG SCH
...

Alphanumeric Method		Hybrid Method	
Entered	Displayed	Entered	Displayed
S	S......	S	S......
E	SE.....	(down arrow)	SAKURA BANK
A	SEA....	(down arrow)	SEAFOOD BAY
R	SEARS	(down arrow)	SEARS

On occasion, fewer keystrokes may be required by entering two characters prior to scrolling. Also, if the subject has extensive knowledge of the list, he or she can enter a character that will place them at the other end and scroll up (e.g., "T" and two up arrows for SEARS).

To enter a destination, the subject entered in the name first (up to 14 characters including spaces). Keying was somewhat confusing. Notice that many of the keys have two characters on them. The right character was shown in white, the left in yellow. To type the left character, the subject first pressed the yellow up-arrow key (the lower left key on the keypad) and then the key of interest. So, to type a period, the sequence would be "YellowUpArrow, " MPeriod." To get to the numeric field, they pressed the diamond key. In the event that all 14 characters were used, the cursor moved automatically. The next task was to key in the longitude and latitude of the destination, either obtained from a map or from lists of street address ranges and coordinates. Additional details of the entry process are provided later.

Calibration and other functions were also available, but they were not examined. Figure 16 depicts the complete menu of user-accessible functions.

The location entry tasks used the "New Destination" branch of the menu (Figure 16) and terminated at the "Input Coordinates" node. Since the experiment only used portions of the Ali-Scout system, the "Actual Position" submethod was not allowed. The equipment to determine current position was disconnected.

Also, subjects were not asked to do any of the "Special Features" tasks. However, they were not prevented from entering this part of the menu.

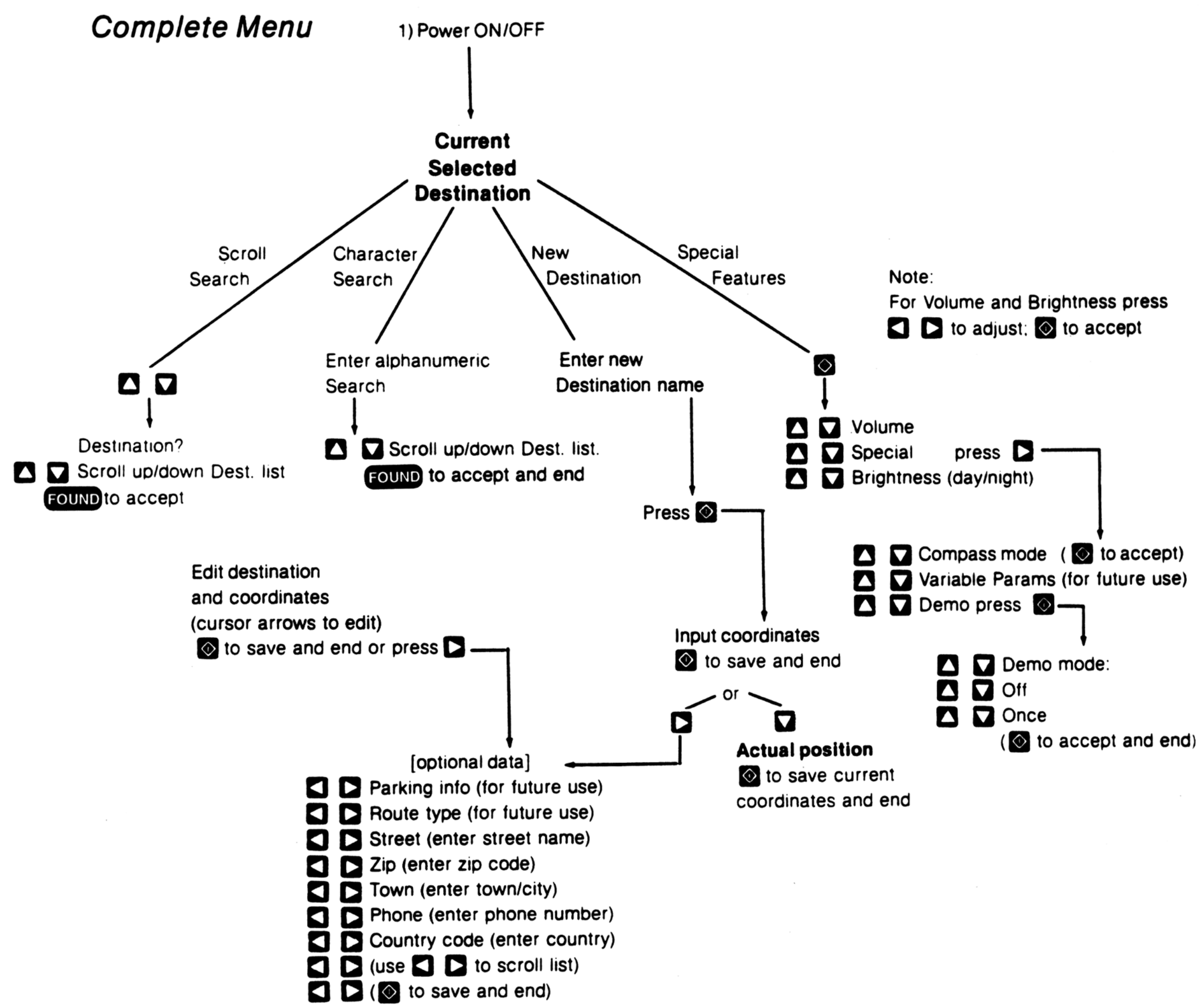


Figure 16. Ali-Scout Menu Structure

The original project plan called for evaluating both real and simulated Display Units under simulated dusk and night conditions. However, pilot tests showed no differences due to illumination for the simulated unit, so only the simulated dusk condition was explored in the main experiment. (Varying light levels were explored for the real display.) In the simulation, all items to be read (LCD text and key labels) were highly legible and, because they were generated by a CRT, were back illuminated and did not require ambient illumination. The worst case was an alphabetic character (J) on the door (contrast ratio 2.9:1). There were numerous situations in which contrast ratios of 10:1 were achieved. Appendix C contains the illuminance and luminance values for the various experimental conditions.

Driving simulator

Interaction with the subjects occurred at two locations in UMTRI. Training and the collection of subject information was conducted in an office. The data collection portion of the experiment was conducted in the Driver Interface Research Simulator.

The automobile simulator consisted of an automobile cab, a retroreflective wall, and a variety of computer and video components. Figure 17 is a simplified drawing of the equipment used in this particular study. It is important to note that subjects never drove the simulator. It simply provided context. During experimental trials a road scene was presented simulating sitting on the right shoulder of a two-lane road.

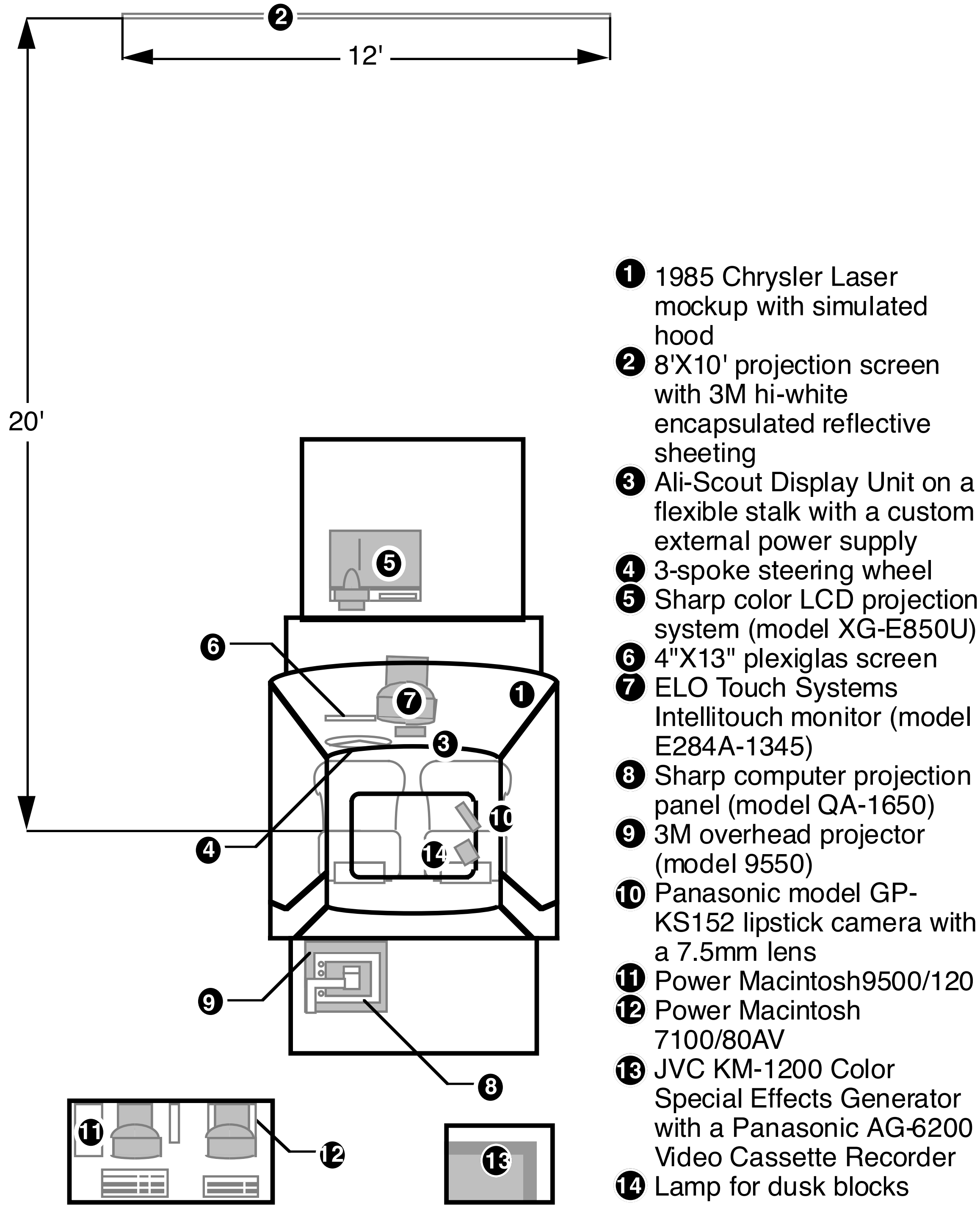


Figure 17. Simulator Layout

Miscellaneous equipment

In addition to the aforementioned equipment, an Ikegami ITC-47 video camera, a tripod, and a Panasonic AG-1970 video cassette recorder were used to videotape the subjects from over their shoulders in the office during the practice and coordinate identification tasks.

Illuminance was measured with a Minolta T-1 Illumination Meter. The illuminance was measured at the location of the Display Unit. Luminance was measured with a Spectra Pritchard Photometer models 1980A-CD and OP. The photometer was mounted on boxes (and stabilized by ropes from above) so that it was in the same position as the driver's eyes (off to the side). Some error may have been introduced because of the awkward posture required by the experimenter to aim and focus the photometer (lean in through the driver’s window and look through the viewfinder with the back of his head pressed against the B pillar of the car).

Test activities and their sequence

After the initial greeting, the subject received a general overview of the purpose of the study, completed biographical and consent forms (contained in the Appendix D and E), and completed a visual acuity test. Following was a fixed set of activities: learning how to use the device (and practice with it), the coordinate search tasks (looking up addresses in books), and the experimental destination retrieval and entry tasks. The experiment ended with miscellaneous tasks to determine subjects' impressions of the device. See Table 10 for additional information. See Appendix F for the complete instructions.

Table 10. Experiment Summary

Activity #	Name	Description
1	Introduction	subject is told purpose of experiment, subject completes biographical and consent forms
2	Videotape	subject watches instructional video on entering and retrieving destinations
3	Practice	subject retrieves 5 locations, then enters 5 locations
	Test-use of manual	subject looks up 3 destinations in manual (point of interest name, intersection of 2 roads, street address)
4	Simulator introduction	subject is introduced to the touchscreen (practice)
5	Test-keypad use	subject completes 5 entry then 5 retrieval tasks (3 times: real interface at dusk, real at night, simulated at dusk), order was counterbalanced.
6	Post-test	subject's eyesight checked, subject completes questionnaire, subject is paid, subject's finger anthropometry is recorded

The learning and practice activities began with a five-minute video tape on the Ali-Scout system (Wallace, Eby, and Gardner, 1995). This tape included instruction on searching for coordinates and entering destinations. Subsequently, the subject was provided with a reduced version of the manual, a sheet with the command menu structure (as previously shown), and a practice sheet of instructions. (See Appendix F.) Subjects used a Display Unit to find a list of locations in a database that included five dummy and five real locations (the Unused and Retrieved columns of Table 11), one at a time. When all of the locations had been found, the subjects were instructed to insert a list of five locations and their coordinates (the Entered columns of Table 11), one at a time.

Table 11. Practice Databases

Unused List (dummy)	Retrieved List (real)	Entered List		
		Location	Coordinates	
AMOCO	BP SERVICE	CADE GALLERY	0830845W	422908N
BECKYS CAFE	FIRESTONE	HUNAN PALACE	0832531W	422805N
ECHO PARK SCH	MAYAS DELI	MAIN THEATER	0830840W	422926N
SIEMENS	PLUS-BANK 24	SHELL	0830532W	423534N
STAR DELI	SUBWAY	VILLAGE MARKET	0830901W	423715N

As can be seen from the listing of coordinates, the length and content of all used coordinates are comparable across locations. Therefore, most discussion of entered locations will only focus on the names assigned to the locations.

The last portion of the activities conducted in the office was a coordinate search task (for which name lengths were not comparable). This required subjects to look up coordinates in the Ali-Scout manual. Location identifiers were listed on 3 x 5 inch (7.6 x 12.7 centimeter) cards. The experimenter handed the cards one at a time to the subject to maintain a counterbalanced order. Information requested included Points of Interest (given the name, find the coordinates in a list), Address Ranges (given an address, find the coordinates in a list), and Ali-Scout Maps (given two intersecting roads, find the coordinates on a map). Three different locations were examined for each information request. The order of formats was counterbalanced across age groups. (See Appendix G.)

After the practice and coordinate search tasks, the subject was escorted to the driving simulator. The road scene showed that the subject's car was parked on the side of the road. After the driver adjusted the seat, the experimenter verified that the subject could comfortably reach the touchscreen. The interior lighting was adjusted for the test condition. (In the simulated dusk condition, a small shielded light just above the center console and a second light in the passenger area were turned on.)

The first block of trials consisted of five retrieval tasks followed by five entry tasks. (Appendix H lists the database used for retrieval tasks.) For each location in the database, the minimum number of keystrokes needed to find the location was determined. The only methods considered for this computation were pure scrolling, alphanumeric, and a simple version of the hybrid method (the first letter followed by down arrows).

The 20 locations were split into 4 groups of 5 locations, with the minimum number of keystrokes being equalized among groups. (See Table 12.) Locations were ordered so that the minimum number of keystrokes (averaged across groups by trial) was just over three. Balancing in this manner facilitates looking at practice effects across subjects. The minimum number of keystrokes for each location and the locations chosen are shown in Tables 12 and 13. Note that the sets are slightly unbalanced (averages shown at the bottom of the table). After the experiment was run, an error was discovered in computing the minimum number of keypresses to reach the first four locations. A down or up arrow must be pressed to enter the scroll mode. The locations that were most readily found through the scroll mode were affected by this discovery. In addition, the location of `VANDENBURG SCH` was erroneously believed to require only one keystroke to reach. A shift activation was mistakenly ignored. The locations in Table 12 that are shown in bold were originally believed to require one less keystroke.

Table 12. Minimum Number of Keystrokes for Retrieval

Stimulus Set			
A	B	C	Dummy
2	3	**3**	5
5	4	3	1
5	2	1	4
3	**2**	5	**4**
2	5	4	2
3.4	3.2	3.2	3.2

Table 13. Retrieval Lists for Each Stimulus Set

A	B	C	Dummy
SAKURA BANK	SEAFOOD BAY	BILL KNAPPS	MONTGMRY WARD
BIR ICE ARENA	PRINT GALLERY	PRIMOS PIZZA	ROYAL OAK DELI
MONTERREY REST	MAJESTIC CAFE	WOODSIDE HOSP	SEARS
MOBIL	VANDENBURG SCH	BIR THEATER	BIR ART GALLRY
BIG BOY	BIR LIBRARY	MONGOLIAN BBQ	PALACE OF AH

In a manner similar to the retrieval tasks, an effort was made to equalize the total number of keystrokes and shifts across orders and across entry trials to facilitate looking at differences due to those factors. (See Appendix I.) There were differences for the individual entry tasks. (See Table 14.)

Table 14. Entry Lists for Each Stimulus Set

Stimulus Set	Name	# Keystrokes	# Shifts
A	NICKS PLACE	12	1
	Q GAS	7	2
	HELENS KITCHEN	15	1
	YAW GALLERY	12	1
	GOODYEAR	8	0
B	FARMER JACK	12	1
	TACO LOCO	10	1
	FIRST OF AM	13	2
	JACOBSONS	9	0
	CHEVRON	8	1
C	LARK REST	10	1
	UNICORN GRILL	14	1
	KROGERS	7	0
	QWIK STOP	11	2
	TUFFY AUTO	11	1
Dummy	LICHT PARK	11	1
	NORDSTROM	9	0
	DISCAFE	7	0
	OAKLAND MALL	13	1
	OLIVE GARDEN	14	2

The order of presentation of the three conditions—simulated, real display at dusk, and real display at night, was counterbalanced. (See Appendix G.)

The subject's visual acuity was tested after the experimental blocks had been completed. Then questions were asked regarding key size, key spacing, display size, display contrast, and whether the system was logical. (See Appendix J.) Subsequently, subjects pressed their finger against a transparency on the face of a copier as if they were pressing a key. A scale on the transparency aided in measuring the finger contact patch.

After completing the experiment, subjects were thanked and paid $40.

RESULTS

Data reduction method

An important contribution of this project was the development of software to obtain time and accuracy data from the videotapes of the trials for the real interface. Specifically, this software was designed to help obtain the trial time, time between keypresses, and correctness of each destination designation. This tool was developed because the Ali-Scout interface is a closed product and connecting recording sensors to the Display Unit would have destroyed it. For the simulation, however, keypress times and keys pressed were automatically recorded by the simulation software, thus the data-reduction software was required only for trials with the real Ali-Scout unit.

The data-reduction software developed, VCRTimeIt 1.0, controls a Panasonic AG-DS550 video cassette recorder with single-frame accuracy. The interface (see Figure 18 on the following page) was written using SuperCard 2.5 for the Macintosh. With VCRTimeIt, each time the user presses a key on the keyboard, the character for that key along with the current VCR counter reading (the time) is added to a list field. The user is free to play the tape at any speed and can choose any key to represent an event.

Normally, the tape was played back at half speed, with the analyst pressing an associated key at approximately the same time as a character appeared (or the cursor moved) on the Ali-Scout display. When subjects pressed buttons that produced no visual change to the display (such as the shift key), the analyst pressed the associated key close to the moment the subject released the button. When the keypresses became frequent (such as when the subject repeatedly pressed the same key) playback was reduced to one-quarter speed. For alphanumeric entries, the associated key was the equivalent lower-case character. For special functions, upper case characters were entered (such as “D” for diamond, “C” for cancel, and "Y" for shift). Errors introduced from analysts keypresses (to obtain times) were extremely small. (See Manes, Green, and Hunter, 1996b.)

VCRTimeIt was developed, instead of using existing time study programs, such as Activity Catalog Tool (A.C.T.) (Segal and Andre, 1993) and EventRecorder (Berger, Walton, and Wurman, 1993), for four reasons. First, because VCRTimeIt is directly linked to the VCR, the user can vary the speed and even reverse the direction of the tape at any point during the analysis, maximizing the speed of the analysis and allowing for easy error correction. A.C.T. and EventRecorder both require a constant playback speed throughout the analysis. For both A.C.T. and EventRecorder, pausing the tape during the analysis is difficult because the user must press a key on the keyboard and a button on the VCR at the same time. Pausing tends to occur when the analyst is interrupted or needs a break.

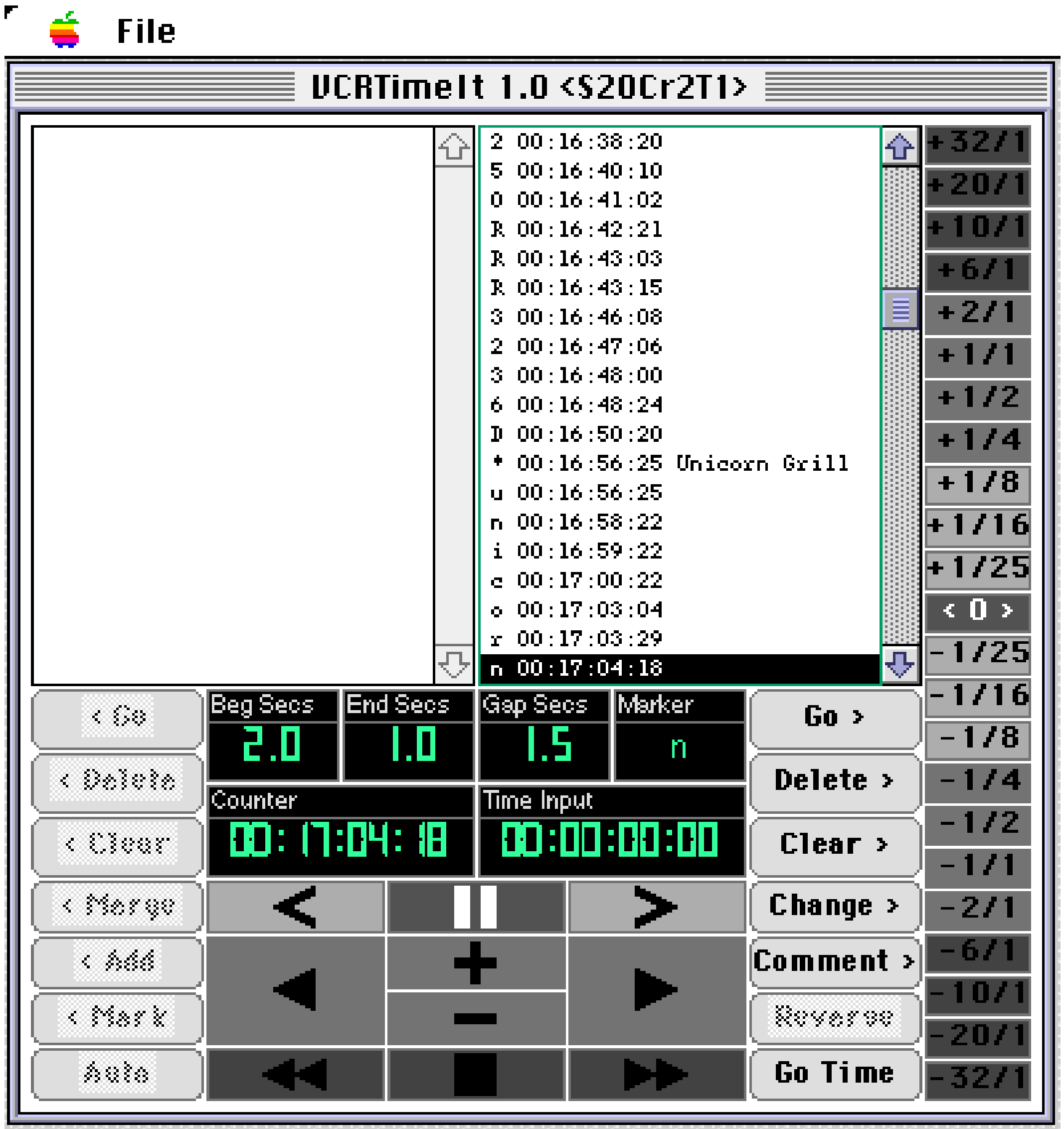


Figure 18. VCRTimeIt 1.0 User Interface

Second, VCRTimeIt can automatically cue the tape to any event that has already been marked, thus allowing the user to easily find and check events of interest, a feature neither A.C.T. nor EventRecorder support. Third, data collected with VCRTimeIt can be edited at any time. With A.C.T., the analyst cannot even see the output file until the analysis is complete. Finally, VCRTimeIt records time data to the nearest 1/30th of a second, while EventRecorder only does so to the nearest second.

After the initial pass at the data, two blocks of trials (325 total keypresses) for one subject were reanalyzed to verify that the data-reduction procedure was repeatable. There were only two discrepancies in the number of keypresses between the original and repeated analysis, and the time difference between the corresponding keypresses never exceeded 0.3 seconds, except for a single keypress where the difference was 0.5 seconds. The vast majority of times were either equal or different by 0.1 seconds.

Analyst delays were not perceptible since the analyst could predict when events would occur.

In spite of these checks, there is a possibility that some systematic errors could have occurred, although these are unlikely to have affected the total destination and retrieval times (the basis for the data analysis). Perhaps the most probable type of error would be the analyst missing errant keypresses which had no effect on the functioning of the Ali-Scout. For example, it would be difficult to tell if a subject accidentally pushed K instead of the zero button (two adjacent buttons) during coordinate entry because the system provides no feedback if a letter is pushed when only a number is allowed. A second type of error would result from the analyst being unable to distinguish whether the shift key was pushed twice in a row or not at all. This would be an issue for some subjects who occasionally did not push the buttons hard enough for them to register.

Because the method for obtaining the entry and retrieval times consisted only of measuring the time from the first to last keypress, neither the subject's thinking time (the time between receiving the card and the first keypress) nor confirmation time (the time following the final keypress) were captured. This method was used because the exact time a card was handed to each subject could not be established, and the exact time the subject finished could not be determined (because the subjects were inconsistent in their use of the "found" key). An unfortunate side effect of this method is that zero times were sometimes obtained for one of the destination retrievals (`WOODSIDE HOSP`) because only a single keypress was necessary if the character search method was used.

Overview of the entry and retrieval data

To recap, of the 30 name cards shown to each of the 36 subjects, 15 were destinations to be entered into the Ali-Scout, and the remaining 15 were to be retrieved from it. The cards were divided into three sets, referred to in this report as A, B, and C. The cards in each set were always shown in the same order: The five retrieval cards were shown first, followed by the five entry cards. Each set was presented under a different experimental condition (real device with dusk lighting, real device with night lighting, or the simulated device at dusk), but the card set-condition pairings were rotated so that each set was seen in each condition exactly one third of the time.

Times were recorded from the first keypress to the keypress completing the entry. This does not include use of the "found" key since it was used irregularly, nor the 1 to 2 seconds subjects were observed to spend planning their response. There are no times missing from the data set, so there are 540 (=36 x 15) times for destination entry and 540 times for destination retrieval. The histograms of these times (Figure 19) reveal a skew to the right—the extreme outliers are all very long, rather than very short, times. It is for this reason that median, rather than mean, times give a more accurate sense of "typical" times, since the median is not influenced by extreme values. The two panels in Figure 19 have different time scales, selected so all data points could be displayed. The interquartile range (IQR) is the gap between the 25th and 75th percentiles (the first and third quartiles) and is a measure of dispersion which is far less sensitive to outliers than the standard deviation. However, even though medians and IQR are more sensible choices than the traditional mean and standard deviation for giving an overall sense of subject behavior, ANOVA makes implicit use of means. Departures from normality were not sufficient to rule out the use of ANOVA. Thus, means will appear throughout this report wherever comparisons must be made among groups of times.

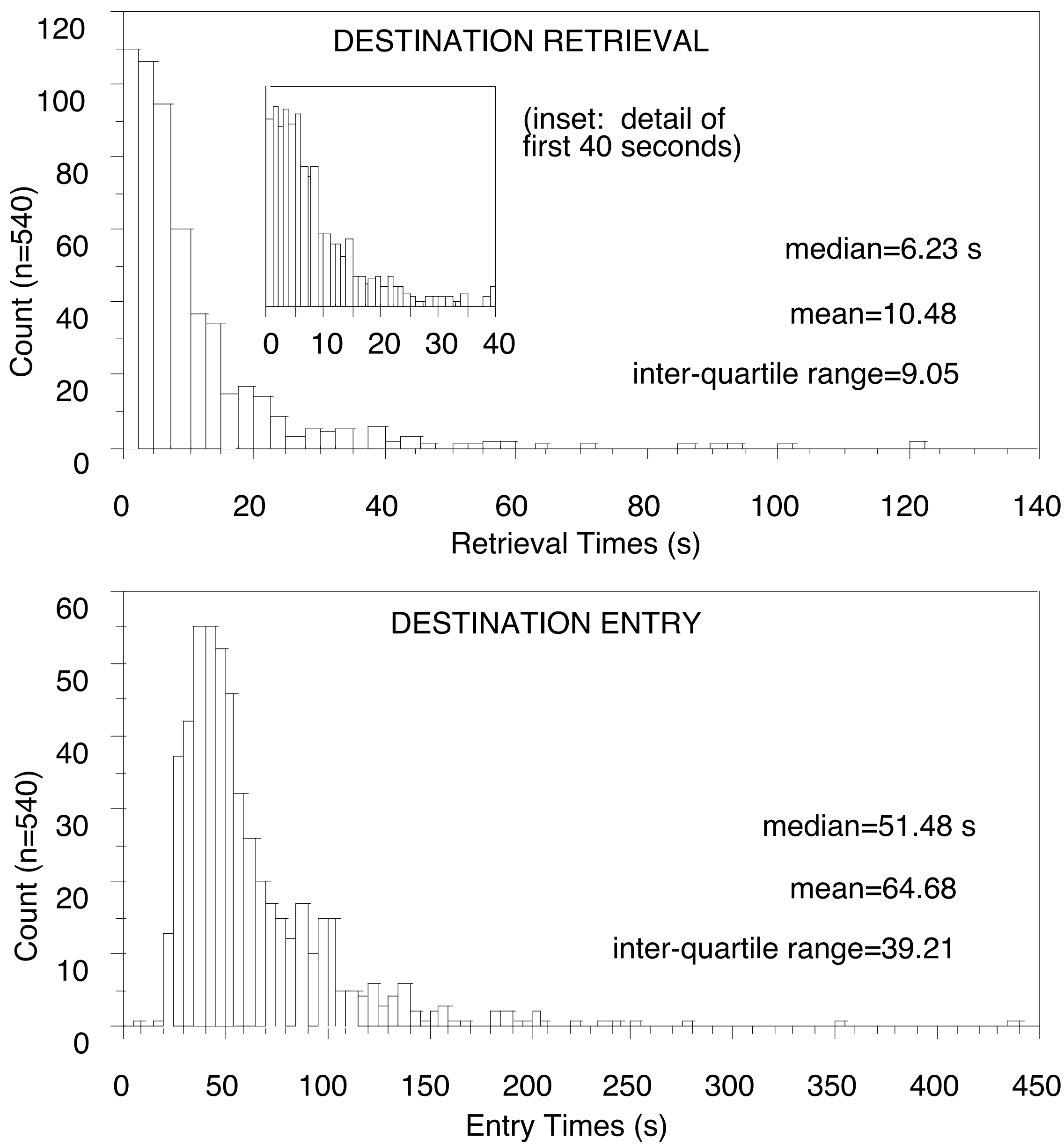


Figure 19. Histograms of retrieval and entry times.

Subjects made many more uncorrected errors, on average, on the entry task than on the retrieval task. Of the 540 trials, there were only 8 uncorrected errors for retrieval (a rate of 1.5 percent) but 54 errors for entry (10.0 percent). An uncorrected error is an instance in which the subject continued with the experiment (believing that the information on the card had been correctly retrieved or entered) when in fact the destination had not been correctly retrieved or entered. Thus, an error was counted only if the end result was incorrect, not if the subject typed incorrect keys and then corrected them while completing the task. More will be said about errors in the next section.

What were typical entry and retrieval times (and error rates) for destinations?

Table 15 summarizes the median, maximum, and (for the sake of completeness) mean for each of the cards, and Figure 20 gives a graphical depiction of the median and mean values for each destination to give a sense of their variability.

Table 15. Median, Maximum, and Mean times for each of the 30 cards.

Retrieval Times (s)				Entry Times (s)			
Place Name	Median	Maximum	Mean	Place Name	Median	Maximum	Mean
SAKURA BANK	3.47	101.88	8.80	NICKS PLACE	60.16	209.95	77.00
BIR ICE ARENA	12.00	121.75	19.00	Q GAS	47.67	275.88	69.55
MONTERREY REST	9.58	120.58	16.34	HELENS KITCHEN	55.25	203.22	72.85
MOBIL	3.98	55.40	8.68	YAW GALLERY	54.19	252.55	67.82
BIG BOY	4.57	51.83	7.47	GOODYEAR	39.45	135.73	51.05
SEAFOOD BAY	8.27	94.90	17.10	FARMER JACK	67.55	351.30	84.31
PRINT GALLERY	6.82	16.05	7.52	TACO LOCO	52.50	151.70	57.98
MAJESTIC CAFE	2.37	21.30	3.73	FIRST OF AM	54.98	159.20	64.55
VANDENBURG SCH	3.56	52.97	9.68	JACOBSONS	48.28	185.70	60.30
BIR LIBRARY	9.97	58.13	14.05	CHEVRON	44.00	100.63	46.96
BILL KNAPPS	4.79	62.60	8.70	LARK REST	61.74	243.73	72.03
PRIMOS PIZZA	6.15	57.63	10.93	UNICORN GRILL	55.59	238.53	74.17
WOODSIDE HOSP	0.38	19.35	1.83	KROGERS	43.96	101.52	47.28
BIR THEATER	9.83	30.77	12.70	QWIK STOP	54.43	436.45	73.18
MONGOLIAN BBQ	7.27	39.77	10.69	TUFFY AUTO	45.67	131.72	51.12
Overall	6.23	121.75	10.48	Overall	51.48	436.45	64.68

Note: Retrieval always begins with the place name "AT THE START" (the first alphabetic entry) shown.

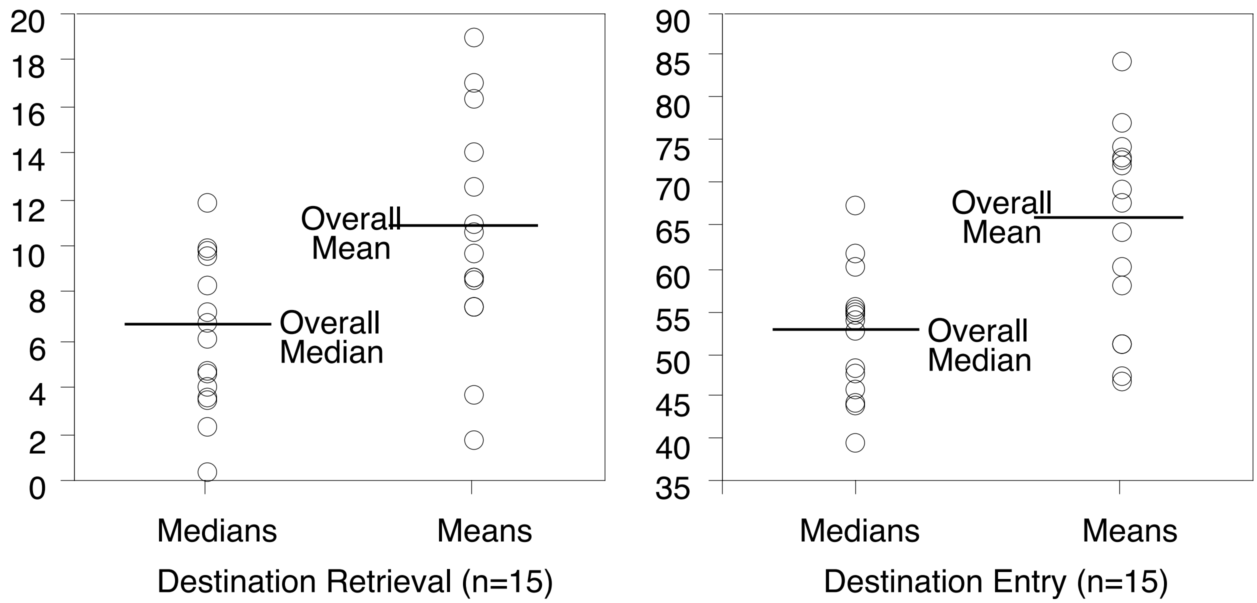


Figure 20. Distribution of entry and retrieval of the means and medians times across locations (in seconds).

Table 15 shows that a median time for the retrieval task from first keypress to final keypress was a bit more than 6 seconds, yet the maximum time exceeded two minutes. Similarly, the median entry time is around 51.5 seconds but could be as long as <u>seven</u> minutes. The times given above for entry are probably closer to reality than those for retrieval, for a couple reasons. First, because retrieval times are shorter, the lengths of time spent before the first keypress and after the last (which are missing from the times recorded in Table 20) are a greater proportion of total retrieval time than of total entry time. Second, retrieval times—particularly if the subject scrolls through the whole list to find the desired location—are dependent on the number and sequence of destinations stored in the memory of the Ali-Scout, whereas entry times are not.

Table 16 gives the total number of errors for each destination for the 36 subjects. (To determine error rates, divide the number of errors by 36.) Because entry involves typing data into the Ali-Scout and retrieval only involves finding data that are already there, entry errors were much more common than retrieval errors. As noted earlier, these errors are only of the type that were never corrected by the subjects; Table 21 does not, for example, include information on missed keypresses that were immediately corrected.

Table 16. Numbers of errors for both the retrieval and entry cards.

Retrieval Task Errors	
Place Name	Errors
SAKURA BANK	0
BIR ICE ARENA	1
MONTERREY REST	1
MOBIL	0
BIG BOY	0
SEAFOOD BAY	0
PRINT GALLERY	0
MAJESTIC CAFE	0
VANDENBURG SCH	1
BIR LIBRARY	5
BILL KNAPPS	0
PRIMOS PIZZA	0
WOODSIDE HOSP	0
BIR THEATER	0
MONGOLIAN BBQ	0
Overall Rate	1.5%

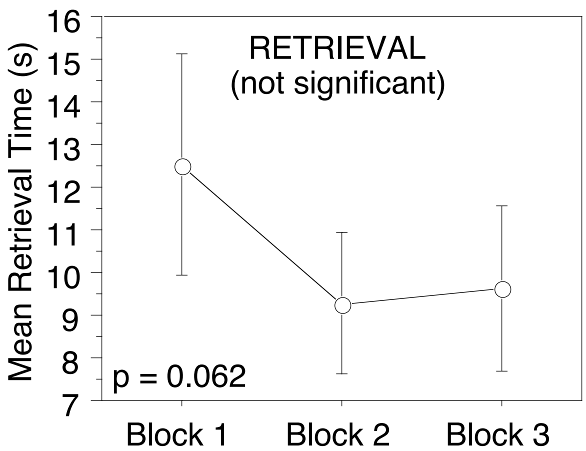
Entry Task Errors	
Place Name	Errors
NICKS PLACE	6
Q GAS	4
HELENS KITCHEN	6
YAW GALLERY	4
GOODYEAR	2
FARMER JACK	2
TACO LOCO	1
FIRST OF AM	4
JACOBSONS	4
CHEVRON	6
LARK REST	0
UNICORN GRILL	5
KROGERS	2
QWIK STOP	6
TUFFY AUTO	2
Overall Rate	10.0%

Although the errors in the retrieval task were too rare to be of any use in analysis, the specific types of errors committed deserve explanation. The high number of errors in retrieving BIR LIBRARY was due to four subjects who scrolled until they reached BIR ART GALLERY and then stopped. The error in BIR ICE ARENA was due to the subject pressing the right arrow key when a space was appropriate. This sent the Ali-Scout into entry mode, an action that can only be reversed by pressing cancel and starting over. The remaining three errors were due to spelling mistakes: BIR LIBRARY was typed as BUR LIBRARY; MONTERREY REST as MONTERRY REST; and VANDENBURG SCH as UANDENBERG SCH. This last error, which was due to typing U instead of shift-U, tended to be difficult for subjects to catch because U and V are difficult to distinguish on the Ali-Scout's display.

Did performance change with practice?

To examine learning, entry and retrieval will be treated separately here (as they will be throughout the analysis). Each subject saw 15 of each type of card, and the question of interest is whether, on average, subjects did better on the later cards than the earlier ones. However, the trials, numbered 1 to 15, should not be considered as separate levels of a single factor in ANOVA since the cards were always ordered the same way in each group of 5. For example, the "SAKURA BANK" card could only appear on the first, sixth, or eleventh trial, so even an existing practice effect might not be evident if the intervening trials consisted of much harder or much easier cards. Thus, the mean times for each block of 5 trials will be considered: trials 1 to 5, 6 to 10, and 11 to 15. This gives 3 levels instead of 15, and the cards in each of the 3 levels are exactly the same, so the effect observed is independent of differences in reaction times for individual cards.

Figure 21 shows the three-level block factor described above. Based on an ANOVA model with one main effect, there was a significant learning effect for the destination entry task (p<0.0001), but not for the destination retrieval task (p=0.062). Specifically, for entry, block 2 and block 3 both have significantly shorter entry times than block 1, but blocks 2 and 3 are not significantly different from each other.



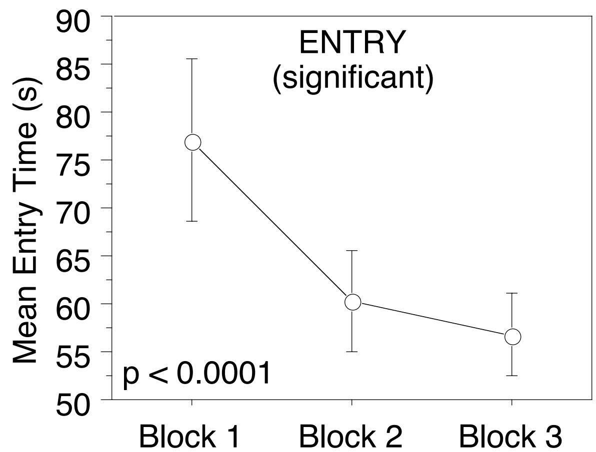


Figure 21. Effect of practice (block number) on task time.
The error bars are 95 percent confidence limits.

These results suggest that the subjects received enough practice on the retrieval task prior to the first block, since no significant improvement occurred after that point. Exploring the block effect a bit further, the age-block interaction is significant (p=0.0012), and the effect plot in Figure 22 shows that it is the middle-aged and older subjects for whom the first block was significantly slower than the other two. Young subjects did not experience such a significant drop in times. Thus, a bit more practice on the entry task than occurred in this experiment was needed, particularly for the benefit of the middle-aged and older subjects.

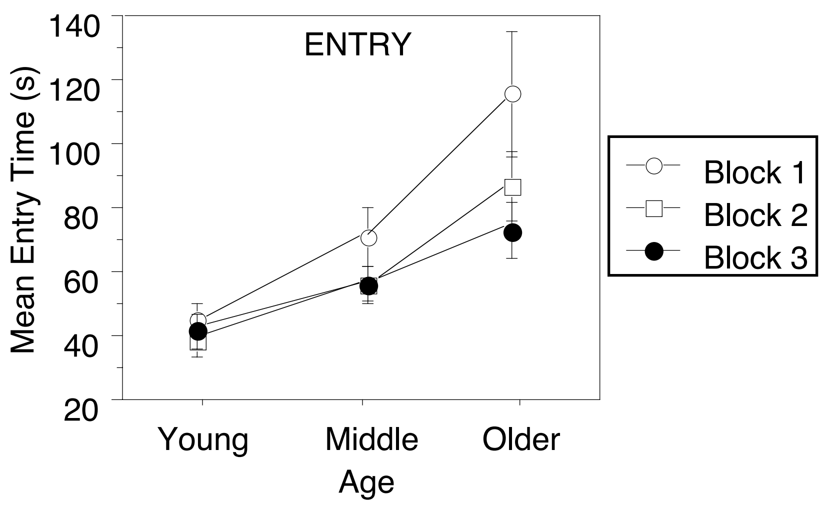


Figure 22. Interaction between age and block number.
The error bars represent 95 percent confidence intervals.

The general pattern of errors was similar to the time data, decreasing slightly with practice, though the effect was not statistically significant. (See Figure 23.) As mentioned above, a similar analysis for the retrieval task would reveal nothing because of the small number of errors.

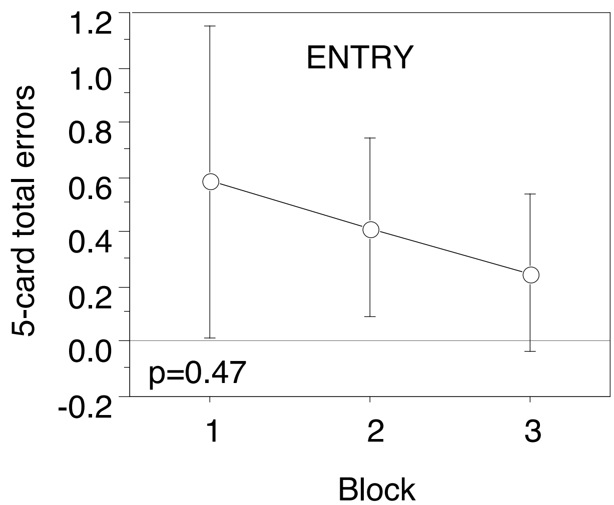


Figure 23. Total number of errors for the destination entry task as a function of practice (block number). The error bars represent 95 percent confidence intervals.

How did performance (time and errors) vary as a function of driver age and sex?

For destination entry, there were enough mistakes overall to allow analysis. The other available measures of performance, completion time for every entry or retrieval task, are the primary performance measures used in the analysis. Figure 24 below shows the individual mean times for both destination entry and destination retrieval. Each age-sex category (e.g., older females) contains six subjects. Even though medians give more representative "typical" times, means are plotted in Figure 24 because the ANOVA tests seen later are based on means. Notice the considerable amount of scatter in the middle-aged men and the older subjects in general.

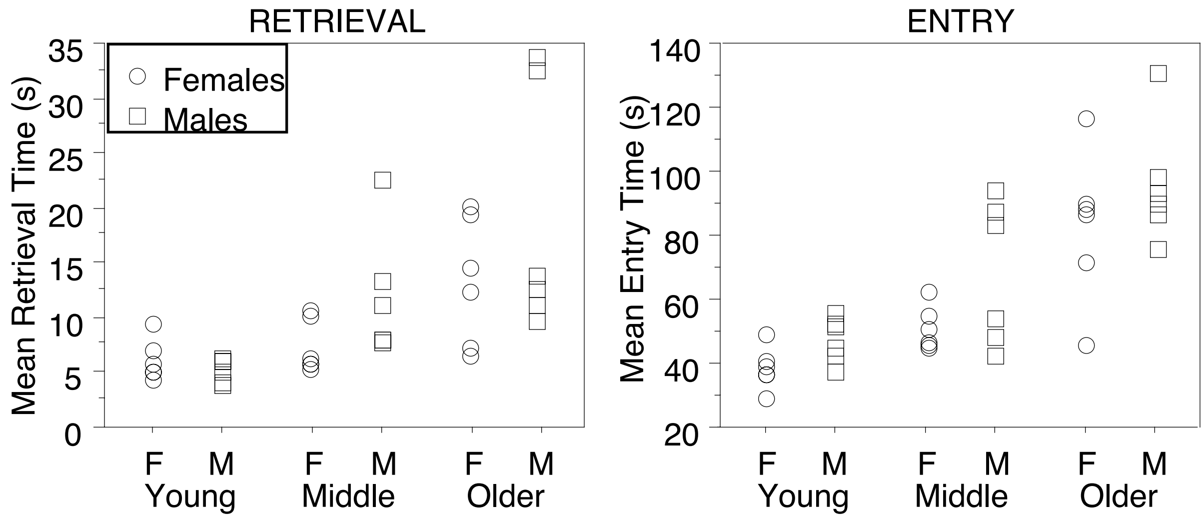


Figure 24. Mean times by age and sex.

ANOVA models of destination entry and retrieval times included sex, age, sex by age interactions, and the effect of subject nested within sex and age. For retrieval time, the effects of sex (p=0.0055), age (p=0.0001), sex*age (p=0.0388), and subject (p=0.0001) were all statistically significant. For entry time, sex (p=0.0001), age (p=0.0001), and subject (p=0.0001) were all significant. ANOVA tables for these analyses appear in Appendix K.

Figure 25 shows the interaction plots for age and sex. Post-hoc tests reveal that every age category is significantly different from every other, for each task. Therefore, it is possible to generalize that women responded more quickly than men and that times increase with age.

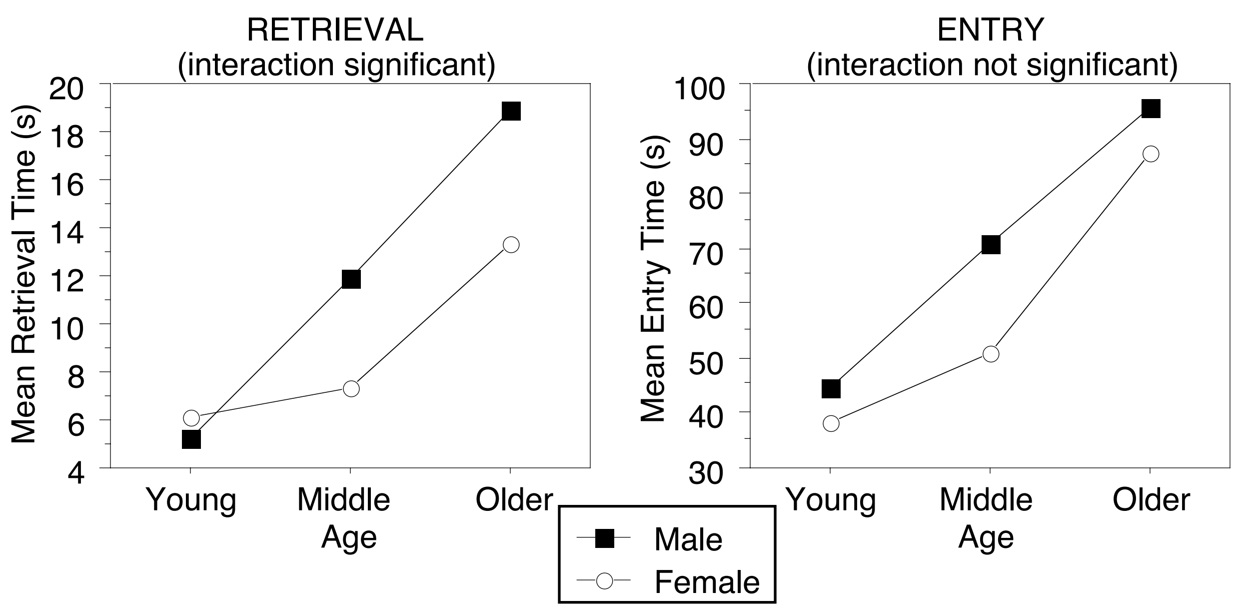


Figure 25. Age-sex interaction plots for destination retrieval and destination entry.

Tables 17 and 18 give median and mean values for each age group and each gender group. To summarize, median entry times for older subjects were double those of younger subjects, with middle-aged subjects midway between them for both entry and retrieval tasks. Men typically took 10 to 20 percent longer than women.

Table 17. Median and mean times for each age group.

Destination Retrieval (s)			
Age Group	Median	Ratio to Young	Mean
Young	4.27	1.00	5.71
Middle-aged	7.27	1.70	9.58
Older	8.59	2.01	16.15

Destination Entry (s)			
Age Group	Median	Ratio to Young	Mean
Young	37.75	1.00	41.41
Middle-aged	52.31	1.39	61.01
Older	75.52	2.00	91.61

Table 18. Median and mean times for men and women.

Destination Retrieval (s)			
Gender	Median	Ratio to Female	Mean
Female	5.85	1.00	8.94
Male	6.39	1.09	12.02

Destination Entry (s)			
Gender	Median	Ratio to Female	Mean
Female	47.68	1.00	58.95
Male	55.57	1.17	70.40

Figure 26 shows the interaction between age and sex in determining the number of errors made on all fifteen entry cards. An ANOVA with number of mistakes as the dependent variable concludes that the age effect is significant ($p<0.0001$), but the sex effect ($p=0.28$) and the age-sex interaction ($p=0.79$) are not. As the figure suggests, a post hoc test confirms that the older subjects made significantly more errors than either the young or the middle-aged subjects, but there was no difference between the latter two groups. The number of errors for the retrieval task is too small to analyze.

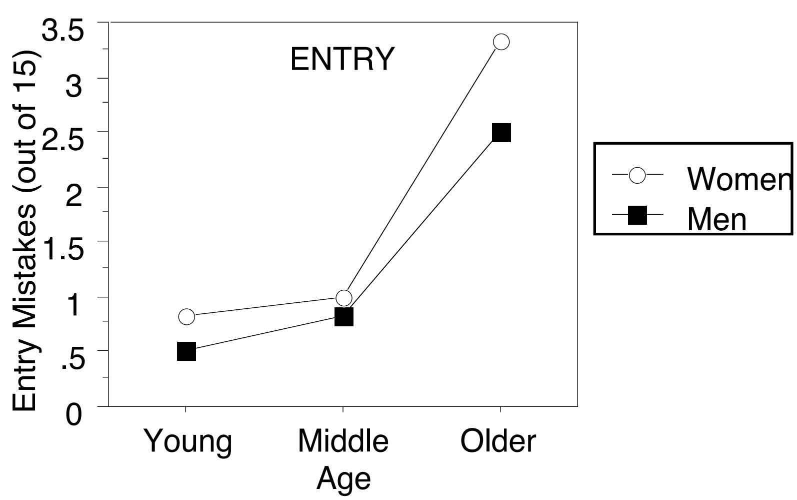


Figure 26. Destination entry errors per subject by age and sex.

What subject factors other than age and sex influenced performance in this experiment?

Of the biographical questions (comfort with maps, prior use of a touchscreen, frequency of computer usage, typing proficiency), only computer usage was significantly related to performance in this experiment. As a reminder, usage was measured using a 5-point scale: 1—never; 2—less than once a month; 3—a few times a month; 4—a few times a week; and 5—every day. The mean response was 3.4, so the subjects were partitioned into a "below average" (responding 1, 2 or 3) and an "above average" (4 or 5) group. The two-level factor thus created has a very strong effect on times (p-values were smaller than 0.0001 in a one-way ANOVA). The means for the two levels of this computer usage factor are given in Table 19. The interaction with the age group factor, seen in Figure 27, is very revealing even though it is significant only in the case of destination entry. Note that the young below-average group only contained one subject and the older above-average group only contained two.

Table 19. Median and mean times for above-average and below-average computer usage.

Computer Usage	Number of Subjects	**Retrieval** (s)			**Entry** (s)		
		Median	Ratio	Mean	Median	Ratio	Mean
Below average	15	9.80	1.91	15.56	76.63	1.73	87.77
Above average	21	5.13	--	6.85	44.27	--	48.18

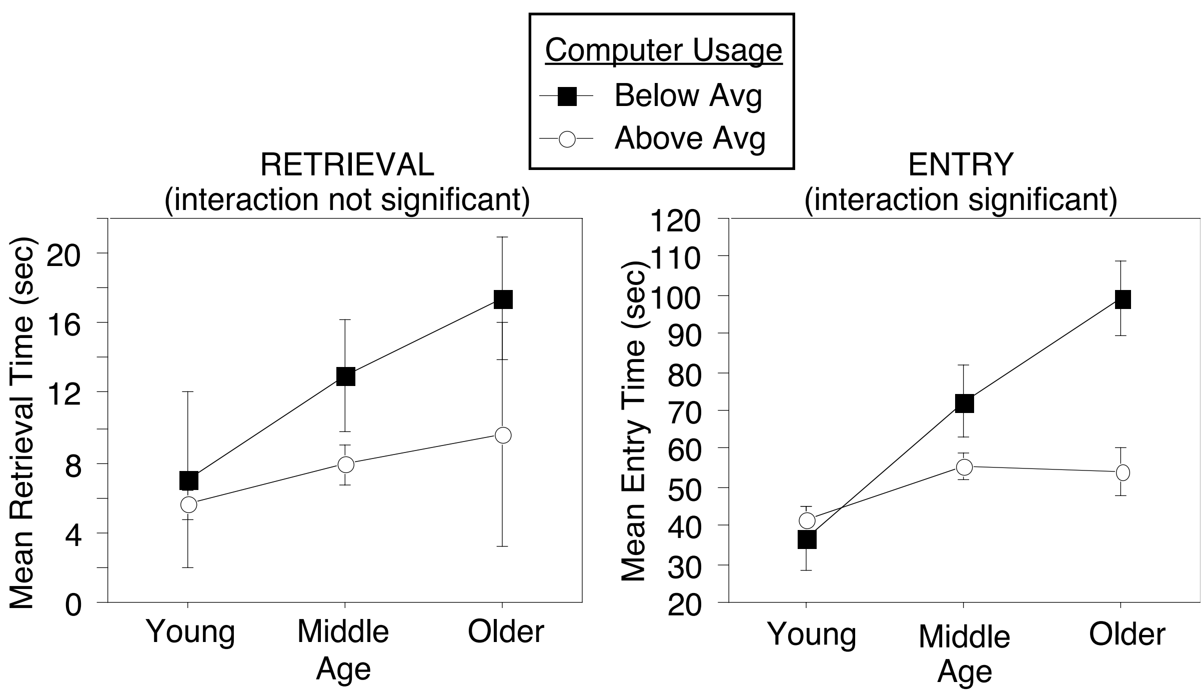


Figure 27. Interaction between age and computer experience. The error bars represent 95 percent confidence intervals.

In an ANOVA of the number of errors committed in the destination entry task (main effects of computer usage and age), there were no significant differences due to computer usage (F(1,32)=0.245, p=0.6243). However, the effect of age was significant (F(2,32)=7.594, p=0.002), consistent with results examining subject differences described earlier. Without the age effect in the model, the computer usage effect is barely significant (p=0.047), mostly because the usage effect is confounded with the age effect.

How did time and errors vary as a function of ambient illumination?

Because the simulated interface (shown on a CRT) was self-illuminated and legibility depended little on ambient illumination, the simulated interface was not considered in the examination of the effects of ambient illumination. Thus, this section compares only the dusk and night conditions for the real Ali-Scout interface.

For destination retrieval, the mean times were 8.89 seconds for the night condition and 7.77 seconds for the dusk condition. This difference is not significant (p=0.2657) nor is the interaction of lighting with age (p=0.8863) or sex (p=0.7814) significant. These results are revealed by the ANOVA summary in Appendix K. For tables of the median values, see Table 20 in the next section.

However, for destination entry, the same ANOVA model reveals a significant difference between dusk and night (p=0.0001) as well as a significant interaction between the lighting effect and the age effect (p=0.0001). (See Appendix K.)

The interaction plot in Figure 28 reveals that the observed significant difference between the night and dusk conditions for the real interface (night mean=65.7 sec; dusk mean=54.0 sec) is mostly attributable to the older subjects. In the night condition, many of the older and some of the middle-aged subjects were unable to see the top row of the keypad because it is unlit. This forced them to count over to the key they were looking for, starting with the first or last key in the row. When attempting to enter a zero, subjects were especially likely, instead, to attempt to enter the letter O (since that is the only round symbol they could see) or a K (which was the last key of the top row).

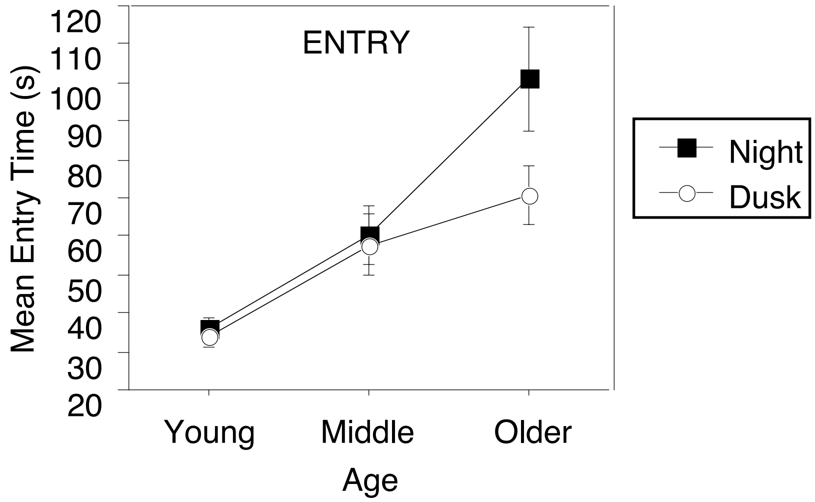


Figure 28. The significant illumination-age interaction for destination entry. Error bars represent 95 percent confidence intervals.

As stated earlier, there were not enough errors committed during the retrieval task to analyze dusk-night differences.

Analysis of the errors for the entry task does not reveal any significant difference between the dusk and night conditions. Each subject saw five cards in the dusk condition and five in the light condition. This means that there were 180 cards seen in each condition. There were 14 total errors made in the night condition and 12 made in the dusk condition (averages per subject of 0.389 and 0.333, respectively). This is not a significant difference, according to one-way ANOVA (p=0.74). Furthermore, there is no significant interaction between the lighting condition and either age or sex as far as the number of errors committed is concerned.

Were the times and errors the same for real and simulated interfaces?

The analysis in this section is very similar to that of the previous section. Whereas the previous section considered only the dusk lighting and night lighting conditions for the real Ali-Scout and disregarded the simulated data, this section will consider all three levels of this condition factor, with the primary emphasis on comparing the simulated level with the other two levels.

Appendix K shows the same two models for the dusk-night comparison but with the additional data for the simulated Ali-Scout included. The same qualitative results are seen for both the retrieval times and the entry times: The condition effect is significant in each (p=0.0001), and the interaction between condition and age group is significant in each (p=0.0001). In Table 20, the median and mean times are given for each of the three conditions. Although the differences between simulated times and other times are significant for both entry and retrieval, the differences are larger for the retrieval times. In the interaction plots, shown in Figure 29, the main qualitative difference between the retrieval and entry tasks occurs with the older subjects. In the retrieval case, the unique condition is the simulated condition, which is much longer; in the entry case, the unique condition is the dusk condition, which is much shorter.

Table 20. Median and mean times for each condition.

Destination Retrieval (s)			
Condition	Median	Ratio to Sim	Mean
Simulated	8.42	1.00	14.78
Night	6.03	0.72	8.89
Dusk	4.79	0.57	7.77

Destination Entry (s)			
Condition	Median	Ratio to Sim	Mean
Simulated	58.65	1.00	74.28
Night	50.32	0.86	65.71
Dusk	44.52	0.76	54.04

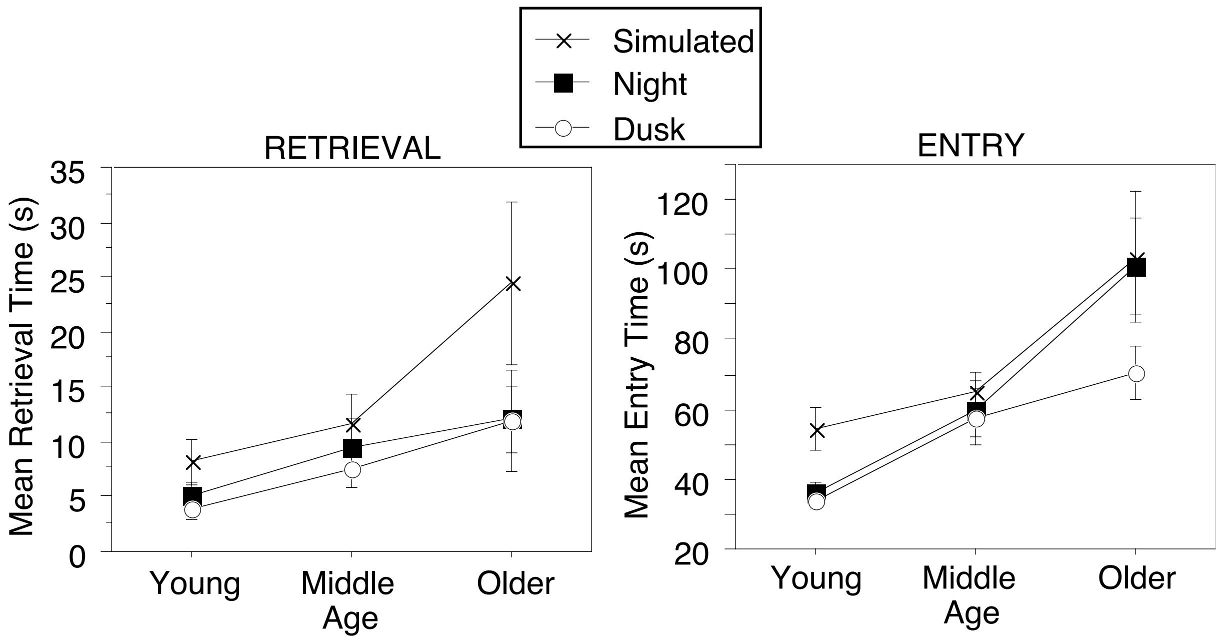


Figure 29. Interactions between the condition effect and the age effect. The error bars represent 95 percent confidence intervals.

There were not enough errors committed during the retrieval task to analyze differences between the simulated Ali-Scout and the real Ali-Scout. However, the errors for the entry task were much greater in number for the simulated version than for either of the other two versions. Figure 30 shows the condition effect, identified by one-way ANOVA as significant ($p=0.033$). The 28 errors out of 180 trials committed on the simulated Ali-Scout was at least twice the number committed in either of the lighting conditions for the real Ali-Scout in the same number of trials (12 errors for the dusk condition and 14 for the night condition). No interaction between condition and age group or sex was significant.

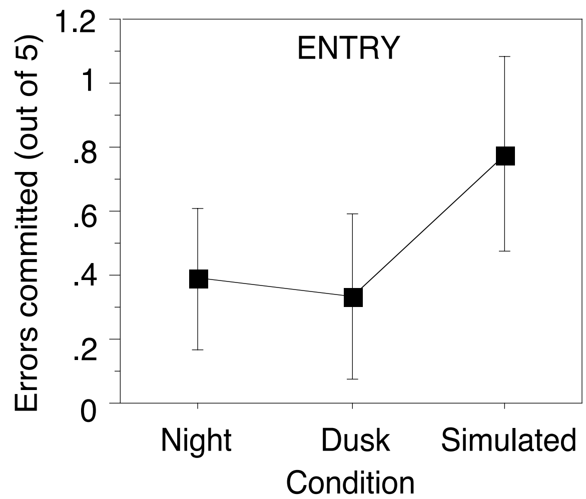


Figure 30. Effect of condition on errors committed.
The error bars represent 95% confidence intervals.

What kinds of interface design problems did drivers of all ages encounter (and how can they be corrected)?

The Ali-Scout (see Figure 31) has several usability problems and physical limitations, some of which affected all subjects and some which affected primarily older subjects. There were 11 problems worthy of note.

Figure 31 The Ali-Scout navigation system

Problem 1. The most frequently observed usability problem was that almost all subjects confused the zero button with the (letter) O button because the symbols representing them are virtually identical (except for color). This was not a size problem. The mean subjective rating of text size (where 1=too small, 2=just right, 3=too large) was 1.9 for the real unit, 1.7 for the simulation (even though the character sizes were identical). Large age differences were not apparent in the data.

Problem 2. Subjects had trouble locating and understanding the function of the shift key. Often, subjects simply forgot to use the shift key when it was required. Also, in darker conditions, many of the older subjects were unable to detect a difference between yellow and white characters (the shift key was used for characters labeled in yellow), leaving the location of the symbol on the key as the only cue.

Furthermore, the yellow upward-pointing arrow used to represent the shift key was ambiguous for some subjects as they tried to use the shift key to move the cursor up a line or were unable to find any shift key when learning to use the system.

Finally, several subjects tried to hold the shift key down while typing the character (as with a typewriter) or pushed the shift key twice (because they were unsure whether their first attempt worked), neither of which produced the desired result.

Problem 3. The space function does not have its own key, but rather appears on the same key as the “L.” This requires the user to press two keys for each space, one of the most frequently used characters. Also, the symbol used to represent a space (essentially the bottom half of a square) was a source of difficulty for nearly all of the subjects.

Problem 4. Subjects, thinking of the device as a typewriter, often entered a space character (instead of the right arrow) to move the cursor to the right , causing characters to be erased instead of skipping past them. During the initial learning period, very few of the subjects were able to figure out how to enter a space even though they had just watched a video which mentioned the method. Also, many of the older subjects and some of the middle-aged subjects forgot how to enter a space by the time the main part of the experiment began, while the younger subjects tended to remember but often hesitated.

Problem 5. Many subjects were often confused about how to advance to the next step when entering destinations. This was seen most frequently when subjects tried to advance from entering a name to entering coordinates. This was not due to problems with text legibility. When asked to rate the display contrast (1=not enough, 2=just right, 3=too much), the ratings indicated contrast was close to adequate (mean rating=1.8 for the real unit, 1.9 for the simulation).

Problem 6. Subjects often used the wrong set of arrows when trying to move the cursor around, sometimes necessitating a large amount of retyping or error correction. Interestingly, when asked in the post-test questionnaire if the real and simulated interfaces were logical, all but one subject responded yes.

Problem 7. The cancel feature required the user to push two buttons simultaneously (when the panel was closed), which sometimes required subjects to push harder than felt comfortable. Very few subjects were confident at first that the system actually intended them to push two buttons simultaneously.

Problem 8. The symbols used to represent “cancel” and “enter,” an X’d circle and a diamond with a vertical line inside it, respectively, were unsuccessful in conveying meaning.

Problem 9. The size and spacing of the keys were criticized by many of the subjects for being inadequate, and, prior to the experiment, many subjects expressed doubt that they would be able to use such a cramped keyboard. In the subjective evaluation, the mean rating of key size was 1.3 (1—too small, 2—just right, 3—too big) for the real Ali-Scout unit, 1.5 for key spacing. For the simulated Ali-Scout unit, the ratings were 1.6 and 1.5. There were no age-related differences apparent under statistical evaluation. However, a quick examination of the results suggested that there may have been differences had there been a higher resolution for the subjective scale.

The significant difference between women's and men's retrieval and entry times is undoubtedly the result of many factors, but one which may have some influence is finger size. Figure 32 shows the results of the anthropometry analysis in which each subject's finger contact width was measured. The width of an Ali-Scout button is 6.0 millimeters, and the space between adjacent buttons is 3.0 millimeters. This suggests that 12.0 millimeters is the maximum width of a finger if no contact with other buttons is to occur. Of the subjects in this study, 11 of the 18 women and 16 of the 18 men had finger contact patches wider than 12.0 millimeters. In the judgment of the experimenters, subjects in this sample of adults did not seem to have unusually fat fingers.

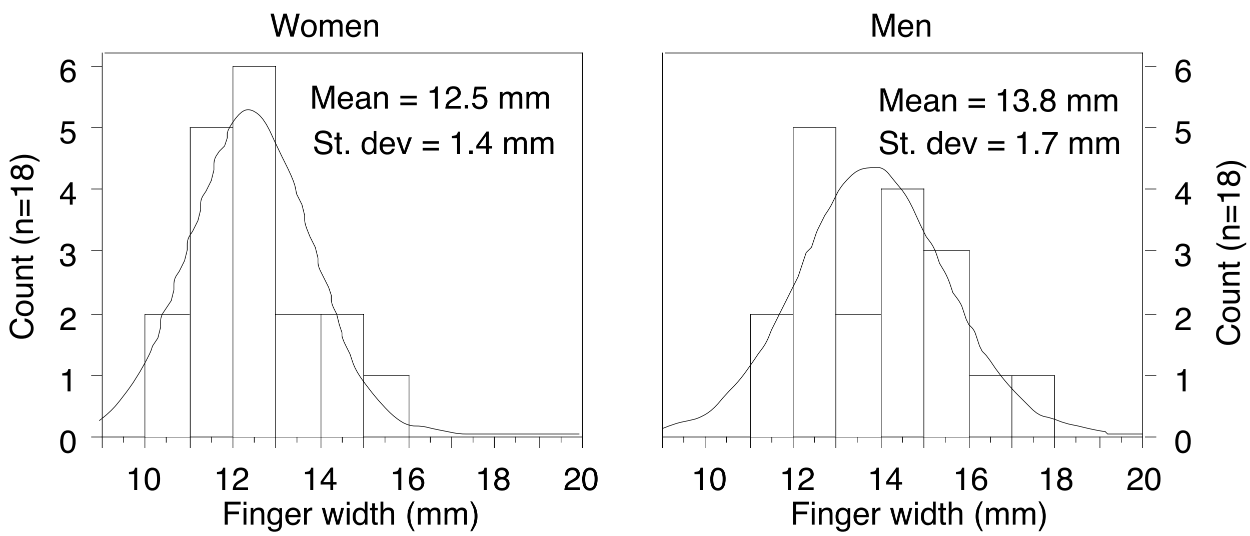


Figure 32. Distribution of finger contact widths for the 36 subjects, split by gender. Normal curves with the same mean and standard deviation are overlaid.

Problem 10. The lack of feedback from the key mechanisms made keying difficult. In particular, since there was no distinct bottoming point, subjects did not always provide the proper amount of pressure. There were also many instances where subjects pressed and released a key and then waited for a response but without effect, as the key had not been pressed hard enough.

Problem 11. Finally, the hinged panel on which the bottom two rows of the keyboard were placed felt flimsy to many of the subjects, causing them to use their thumb to support it from underneath as they typed.

How accurate were subjects in looking up coordinates in the manual?

A key difference between Ali-Scout and other navigation systems is that Ali-Scout uses longitude and latitude, not street addresses or intersections, to identify destinations. As a consequence, users are required to refer to a manual to obtain the coordinates for each destination they wish to enter into the Ali-Scout. The manual is divided into three sections: maps (which can be used to look up the coordinates of street intersections), address ranges, and points of interest. Thus, subjects were asked to look up three sets of coordinates from each of the three sections.

The associated error data from all coordinate-finding tasks are presented in Table 21. An error was recorded whenever a subject looked up and reported coordinates that disagreed with the correct coordinates. When searching for intersections on a map (a task for which the error rate was almost 30 percent), several subjects obtained incorrect coordinates from the maps because they traced their finger along the path of the road rather than the appropriate grid line and thus obtained a number that was off by several units. Fewer errors were made for the intersection of Auburn and Ryan. Ryan follows the grid line closely enough for the subject to obtain the correct value no matter which method is used. Auburn dipped down very suddenly at one point, making it more likely that the subject would trace his finger along the grid line rather than the street. These errors tended to be small (1 to 2 tenths of a mile), and since the Ali-Scout unit goes into autonomous mode before the end of the trip, drivers may still be able to find the destination.

Table 21. Coordinate-Finding Errors

Task	Destination Description	Number Errors	Errors (%)	
Intersections	On Map 1, Giddings & Walton	12	33.3	28.7
	On Map 2, Auburn & Ryan	7	19.4	
	On Map 3, Franklin & Maple	12	33.3	
Street Addresses	450 12 Mile Rd W	16	44.4	23.2
	2300 Coolidge Hwy.	7	19.4	
	4429 Sashabaw Rd	2	5.6	
Points of Interest	Troy Union School	0	0	0
	Glen Oaks Golf Course	0	0	
	Nicholas George Theater	0	0	

Address-range coordinate errors (which accounted for 23 percent of the trials) were most likely due to the subject accidentally choosing the wrong range or being unable to find the correct range because ranges were listed in numerical order by town for each street, rather than simply numerical order for each street. In addition, one of the difficulties in finding the correct coordinates for 450 12 Mile Rd W was that it was often confused with 12 Mile Road, which was listed in the preceding column of the manual.

Finally, the absence of errors in finding coordinates for points of interest is most likely due to the manual listing them in alphabetical order, and the destinations chosen for this experiment did not require the subject to choose between more than one address.

Although no statistical analysis was performed to determine times for the coordinate-finding task, it is estimated that subjects took from 40 seconds to over 1 minute for maps, 30 to 45 seconds for address ranges, and 15 to 30 seconds for points of interest. These experimenter estimates correspond with the error data, and the reasons for the time differences should follow those outlined previously. In addition, the times for the map would tend to be longer because the streets are not indexed, forcing the subject to search the whole map to find the streets. Many of the subjects took a long time to find 450 12 Mile Rd W because they did not know if numbered streets were listed by their spelling or at the beginning or end of the section.

CONCLUSIONS AND DISCUSSION

How can the analysis protocol be improved?

A major development of this project was the creation of a tool for controlling frame-accurate VCRs and using that tool to obtain reasonably accurate keystroke time data. The analysis method proved to be reliable. While tools for this purpose are commercially available, they tend to be quite expensive and are not perfectly matched to the analysis tasks at hand.

This project would have taken several months less time and cost considerably less if the navigation system provided a means for directly recording keystroke entries and screen changes. Navigation hardware developers should incorporate such a capability in development systems. The absence of such features discourages the conduct of human factors studies, leading to systems that are more difficult and less safe to use.

What were typical entry and retrieval times (and error rates) for destinations?

The mean entry time was 65 seconds; the median was 52 seconds. The mean retrieval time was 10 seconds; the median was 6 seconds. Thus, entry times were 6 to 9 times greater than retrieval times for stored destinations. The difference between the means and medians was so great because of the presence of several extremely long times, which influence the mean more than the median. Because of these extreme outliers, the median gives a better sense of a "typical" time than the mean.

It should be recalled, however, that these times do not include the subject's thinking time required for planning and confirmation. By observation, those times were typically 1 to 2 seconds for entry and 1 to 2 seconds for retrieval. If the subject was confused, these times could be much longer. Further, for destination entry, a significant time was required to find coordinates on lists or on maps, a point discussed later in this section.

Error rates were 1.5 percent for retrieval, 10 percent for entry, nearly a factor of 7 difference.

Did performance change with practice?

Entry times, retrieval times, and entry errors all decreased with practice, but practice effects were statistically significant only for entry times. From the first to the third practice block times decreased by about 20 percent. Thus, by some criteria, subjects were moderately proficient at retrieval-related tasks before the first block.

How did time and errors vary as a function of driver age and sex?

There were large significant differences due to driver age and sex. For retrieval, median times were 5.9 seconds for women and 6.4 seconds for men (with means of 9 and 12 seconds, respectively). These suggest a difference of 9 percent. There were too few errors to examine either sex or age differences for retrieval.

The median entry times were roughly 48 seconds for women, 56 seconds for men (with means of 59 and 70 seconds respectively). Hence, men took about 17 percent longer to enter destinations. However, error rates for the completed entry were about the same.

Differences due to age were much larger. For retrieval, the young, middle-aged, older driver median times are 4.3, 7.3, and 8.6 seconds (with means of 5.7, 9.6, and 16.2 seconds). Hence, the young-old times differ by a factor of 2. The median entry times were 38 seconds for young subjects, 52 seconds for middle-aged subjects, and 76 seconds for older drivers (with means of 41, 61, and 92 seconds, respectively). This is again a factor of 2 for the young-old difference. The difference is even more than double when mean times are compared instead of median times because the older age group tended to include more extreme outliers, with the result that the mean time for the older group is more skewed than for the other two groups.

Differences in destination entry error rates were even larger. For young and middle-aged subjects the error rate was approximately 5 percent. For older subjects, the error rate was 20 percent, a factor of four difference.

What subject factors other than age and sex influenced performance in this experiment?

Of the factors examined (comfort with maps, prior touchscreen use, frequency of computer use, typing proficiency), only computer usage was correlated with performance. This effect is not simply due to age differences; even though there was on average more computer experience represented in the sample of young subjects than in the older group, the effect of computer experience was also seen within age groups, particularly the middle-age and older groups.

How did time and errors vary as a function of ambient illumination?

Mean retrieval times were approximately 8 seconds under dusk conditions, 9 seconds at night, a difference (about 10 percent) that was not statistically significant. (Means are reported here instead of medians because ANOVA is based on means, and this section and the next concern only comparisons using ANOVA. (The medians may be found in the results.) Mean entry times were 54 seconds at dusk, 66 seconds at night (22 percent greater), a statistically significant difference.

Particularly noteworthy were problems older drivers had in the night condition. For them, retrieval times were 70 seconds at dusk, 100 seconds at night, much greater than other groups in the sample. While part of the difference may be due to experimental artifacts (nonuniform illumination of the device with particular difficulty in seeing the top row), they do not completely account for the age differences. This finding emphasizes the need to examine the legibility of self-illuminated ITS products under nighttime conditions using the least capable subjects, namely older drivers.

There were no statistically significant dusk-night differences in terms of errors.

Were the times and errors the same for real and simulated interfaces?

No. The mean entry times were 54 and 66 seconds for the dusk and night conditions with the real interface, and 74 seconds for the simulated interface. (The associated medians were 44, 50, and 58 seconds.) Thus, tasks using the simulated interfaces took roughly 25 percent longer to complete. For entry times, the comparable values were 8, 9, and 15 seconds (with medians of 5, 6, and 8 seconds). In that case, the difference is much larger, nearly a factor of 2. A major reason for these differences is how older drivers responded at night.

Also differing was the number of errors (12 for dusk, 14 for night, and 28 for simulated); the number in the simulated condition was greater by a factor of 2. Even if the times and errors are different, it may be possible to scale data from simulated interfaces to predict performance with real interfaces, although interactions with age complicate scaling.

What kinds of problems did drivers of all ages encounter (and how can they be corrected)?

Problem 1. Zero and the letter O were confused.

These two characters look alike and were therefore mistaken for each other. Solutions include adding a slash to the zero and placing a border around the numbers to group them together. A more radical solution would be to completely redesign the keyboard so each key face is used for only one character.

Problem 2. Use of the shift was confusing.

While subjects were shown how to use the shift key, some forgot. In part, this was because the toggling model for shift key use (press shift, then the key to be shifted) did not fit the typewriter/computer model (hold the shift key down, then press the key to be shifted). One step in the right direction would be to have the display indicate whether the system was in shift mode (via a light, tone, or LCD graphic).

Identifying the shift key was a problem. The color differences between the white (unshifted) -yellow (shifted) keys were not perceptible to some older drivers. This aspect of the problem could be overcome, in part, by changing the font of one of the characters on each key or using a more distinguishable color code. Also, the graphic used to represent shift was easily confused with the various arrow/cursor keys provided. Additional changes to the shift graphic (e.g., filling it in or indicating that it is to be used with the right-side character of each letter pair) may help overcome selection of the wrong key.

Problem 3. The space key was too difficult to access.

Use of the space key was quite common in destination entry. However, two keystrokes were required to enter a space. Further, the typewriter model (a large bar below all other keys) was not supported by the interface. Providing a space bar that fits the accepted user model would require redesigning the keyboard. Less costly improvements include making the space a separate button and using a more easily understood label for it.

Problem 4. The space key was misused.

Some subjects thought the space key would behave as it does on a typewriter. They did not understand that spacing over would erase, not merely move the cursor. It is not apparent how to solve this problem.

Problem 5. How to change fields was unclear.

This occurred after a name was entered and the next step was to enter coordinates. One option might be a graphic on the keypad showing how the cursor keys could be used to change fields.

Problem 6. The two sets of arrow keys were confused with each other.

The open-arrow and closed-arrow keys look too similar and their functional difference is unclear. The open arrow keys controlled the cursor, allowing movement one character up, down, left, or right. The solid arrow keys (also on the front panel) were for scrolling up and down in the stored list of destinations and for accessing special menus (e.g., parking information and route type). One possible way to solve this problem would be to enclose each set of keys with a border and provide a label indicating their function.

Problem 7. Having to push two keys simultaneously to cancel was not intuitive.

Although requiring simultaneous keypresses can prevent accidental activation of unwanted functions, it is an unfamiliar concept to many and the existence of such a feature may never be comprehended. A possible solution would be to add a label such as "push both" underneath the cancel symbol. Also, simultaneous keypresses would be physically easier if the buttons provided better feedback.

Problem 8. Several key labels were uninformative.

Many subjects did not understand the labels for "cancel" and "enter." One possibility for "enter" might be the graphic used on some computer keyboards (↵).

Problem 9. The keys are too small and too closely spaced.

This was a major problem. Small keys on this device reduce the in-vehicle real estate required, lessening the degree to which the stalk-mounted display unit blocks access to other instrument panel controls and displays. Compactness also reduces cost. However, the keys on the Ali-Scout have about one-quarter to one-half the surface area of keys on a hand-held calculator, a device for which minimum key sizes are used for portability. As indicated by the finger anthropometry data, finger sizes of the subjects tested exceeded the width of the keys plus the surrounding space, making it very difficult for subjects to precisely position their fingers and depress a single key. Gloved operation, important for Michigan winters, would have been impossible. Complaints concerning the keys appear in Eby et al. (1996) and were voiced by subjects here. The solution is straightforward: increase the size and spacing. The anthropometric data given in this report, combined with the data in Hoffmann, Tsang, and Mu (1995) could be utilized to predict tradeoffs between entry performance times, key size, and key spacing. However, some adjustments of those data may be needed since the Hoffmann et al. research assumes that subjects know where keys are located. In the experiment conducted here, some visual search for the key was required because of the nonstandard alphabetic sequencing.

Problem 10. Key feedback was inadequate.

Because there was not a distinct feeling when switch contact was made, subjects waited for visual feedback from the real device and both visual and auditory feedback from the simulation to determine when switch closure occurred. Because the feedback was not instantaneous, subjects tended to press much harder and longer than necessary.

For simulated interfaces, it is important that a very fast computer be provided. In fact, earlier versions of the simulation ran on a Mac IIcx and were noticeably slow. While running the simulation on a PowerMac 7200 (and optimizing the code somewhat) improved performance, use of a still faster computer would have been closer to reality since subjects were still noticeably slowed down when trying to repeat the same keystroke several times in a row. Such computers are now widely available. Developers planning to use rapid prototypes for interface evaluation need to make sure that computers are available that are fast enough to run simulations without perceptible delays, especially in response to keystrokes. As computer performance improves, this is becoming less of an issue. However, the tendency is to continue to challenge the boundaries of computer performance by writing more complex simulations.

In addition to improving system timing, use of the real interface could be enhanced by providing keys with more distinctive tactile feedback to indicate closure. In the case of simulated interfaces, some thought needs to be given as to how readily fabricated collapsible overlays might be used to provide feedback. An alternative might be to attach a small vibrator to the subject's fingertip (connected to the simulation computer), that would give the feeling of switch closure.

Problem 11. The hinged panel was not stable.

When entering data, subjects used a variety of strategies to support the lower panel and keep it from moving. Providing a more positive stop or latches to hold the panel open would help.

How accurate were subjects in looking up coordinates in the manual?

Subjects made numerous errors in looking up coordinates in the manual. For finding intersections and street addresses, the error rate was 20 to 30 percent. For points of interest, there were no errors. This finding does not speak well for the effectiveness of the documentation. This finding also raises questions about the viability of a system that requires use of longitude and latitude for on-road navigation. While those coordinates may work well for users of air, sea, and off-road navigation systems, drivers rely on street- or landmark-related information for guidance. While the point-of-interest error data suggest it is possible to design a reliable on-road navigation interface that requires coordinates, the other two data sets suggest that use of longitude and latitude are not desired. Users are unlikely to find a navigation system acceptable if that system directs them to the wrong destination 25 percent of the time (because they selected the wrong location). While some of those errors are small, actual misdirection rates should be even greater as entry errors are likely when the information entered (longitude and latitude) is not meaningful to users.

How did performance with the Ali-Scout interface compare with other systems described in the literature?

Making comparisons with other studies in the literature is extremely difficult to do because the tasks and subject samples differ. As was noted previously, age differences have a major influence on performance, with young-old differences often differing by a factor of 1.5. Here, when only keying times were examined, the difference was a factor of 2. However, interface differences tend to be much less. For example, in Paelke and Green (1993), the ratio of best to worst interfaces (doublepress/phone pad) was 1.7. Fortunately, some of the subject samples here are comparable. Dingus, Hulse, Krage, Szczublewski, and Berry (1991) used three age groups (young, middle, old), while Paelke and Green (1993) had two groups of subjects (young, old). Loring and Wiklund (1990b) did not identify the ages of their subjects.

Interfaces examined varied widely in their functionality, so functions provided on one system are not available on another. Added functionality, if not thoughtfully applied, can make the completion of core tasks more difficult. In several studies, only a phrase is provided describing what subjects did, so it is difficult to know if task objectives are comparable.

Finally, there is some uncertainty about how tasks were timed. While it is believed this generally occurred from the first button press, planning prior to keying is an important part of destination entry and retrieval tasks. However, it is challenging to cleanly delineate when subjects are receiving instructions on how to complete a task and when they are thinking about how to complete it.

Some thought needs to be given to what the basis for comparison should be. The times just for keying in this experiment were mean times of 10 seconds for retrieval and 65 seconds for data entry. An additional 1-2 seconds were required prior to each task for thinking. A major addition unique to this interface is time to look up the coordinates: 40 to 60 seconds for intersections on maps, 30 to 45 seconds for address ranges, and 15 to 30 seconds for points of interest.

Aggregating times together, this suggests that about 11 seconds were required for destination retrieval, but 90 to 120 for destination entry.

Three other experiments described in the literature contain data that may be used for comparison. Loring and Wiklund (1990b) report several tasks that have similarities to those explored here. Recalling a trip with a particular name took 33 seconds, a task that may be similar to the retrieval task explored here, which only took one-third of that time. Deleting a destination, similar to retrieval but with an added step, took 68 seconds. Telling the device to plan a route to a destination and saving the trip plan just driven took 85 and 134 seconds, respectively. Thus, compared with an early version of the interface used for the ADVANCE project, the Ali-Scout interface times were considerably less for retrieval, but comparable for entry.

Dingus, Hulse, Krage, Szczublewski, and Berry (1991) report that entering an unfamiliar destination required 130 seconds, storing a route took 160 seconds, and retrieving a stored destination took 50 seconds. Since the Dingus, et al data is for using a simulated interface written in SuperCard, the comparable times for this experiment (also for using a simulation) are 15 seconds for retrieval, and 74 seconds for entry. It is not apparent whether thinking time was included in the tasks times. Thus, these times are slightly longer for retrieval, but much less for destination entry.

Paelke and Green (1993) provide time and error data for entry of addresses. In contrast to the work of Paelke and Green, the destinations examined here were all in a single county, so entering a city was not required. Furthermore, in contrast to real systems, there was no need to enter a destination mode prior to beginning destination entry. Overall times (the mean of the driving and parked conditions) of 43 seconds were reported for the phonepad, 44 seconds for the Qwerty interface, 55 seconds for the scrolling list (similar to Zexel/Rockwell Pathmaster/Siemens Tetrastar), and 76 seconds for the double press interface (similar to the TravTek interface). Times for parked conditions were 10 to 20 percent less than those for driving. It should be noted that the "driving task" was of low fidelity and subjects did not devote the attention to the task that they would devote to real driving. Hence, the times for destination entry while concurrently driving are underestimates.

The 76 seconds reported by Paelke and Green for the TravTek-like interface may be an overestimate as there were brief instances for which subjects had to wait for the interface simulation to update, something that was much less of an issue for the real TravTek interface. The closest comparable task in Dingus, et al. was entering an unfamiliar destination, a task that required much more than was simulated by Paelke and Green. While it requires many assumptions, it appears that the times for destination entry reported by Paelke and Green are equal to or less than those reported here when only keying is considered, much less when coordinate lookup is included.

Thus, in spite of these provisos and numerous complaints about the keyboard by subjects (and conflict with good human engineering practice), destination retrieval was actually quite quick relative to other systems that have been evaluated to date. However, destination entry was very problematic. The difficulty arose from the use of longitude and latitude as an intermediate step, and use of a keyboard that was too small and presented logical uncertainties.

In closing

For the Ali-Scout interface, retrieval times were approximately 10 seconds, while entry times were just in excess of one minute. When coordinate lookup is included, typical times for destination entry were 90 to 120 seconds. Destination retrieval appears to be faster than other interfaces, while destination entry appears to be much slower. Additional effort needs to be given to describing test conditions in sufficient detail (data base content, device method of operation, response timing, subject selection) so that replication is possible. This is often not the case in similar studies.

Differences in time due to gender were on the order of 20 percent, with women being faster. Age differences were approximately a factor of 2, with older subjects having problems with the interface under the night condition. Older subjects should be the sample for legibility assessments.

Entry times for simulated interfaces were much longer than those for real interfaces, though the general pattern of results was the same. Methods for providing tactile feedback (the feeling of switch closure) need to be explored. This may occur as a consequence of research on virtual reality.

Beyond this experiment, one of the major topics of current discussion is what drivers should be allowed to do while driving. It has been suggested that drivers should not be allowed to perform any destination entry or destination designation tasks while driving. This experiment shows that there are large differences between retrieving a stored destination and entering a destination to store. Furthermore, the literature suggests that there are large differences due to retrieval/entry method and the interface implementation. While what people can and cannot do safely while driving was not explored here, lumping all destination-related activities together does not make sense. Further, because the time required depends on the method, how a particular task is carried out needs to be considered. These differences in method are described in the follow-on report in greater detail.

The research presented here provides engineers and designers with methods to evaluate navigation-interface usability, normative data on the retrieval and entry of destinations, estimates of the individual differences, and a list of problems associated with a contemporary navigation product. This information should be useful to engineers and designers involved in future navigation systems.

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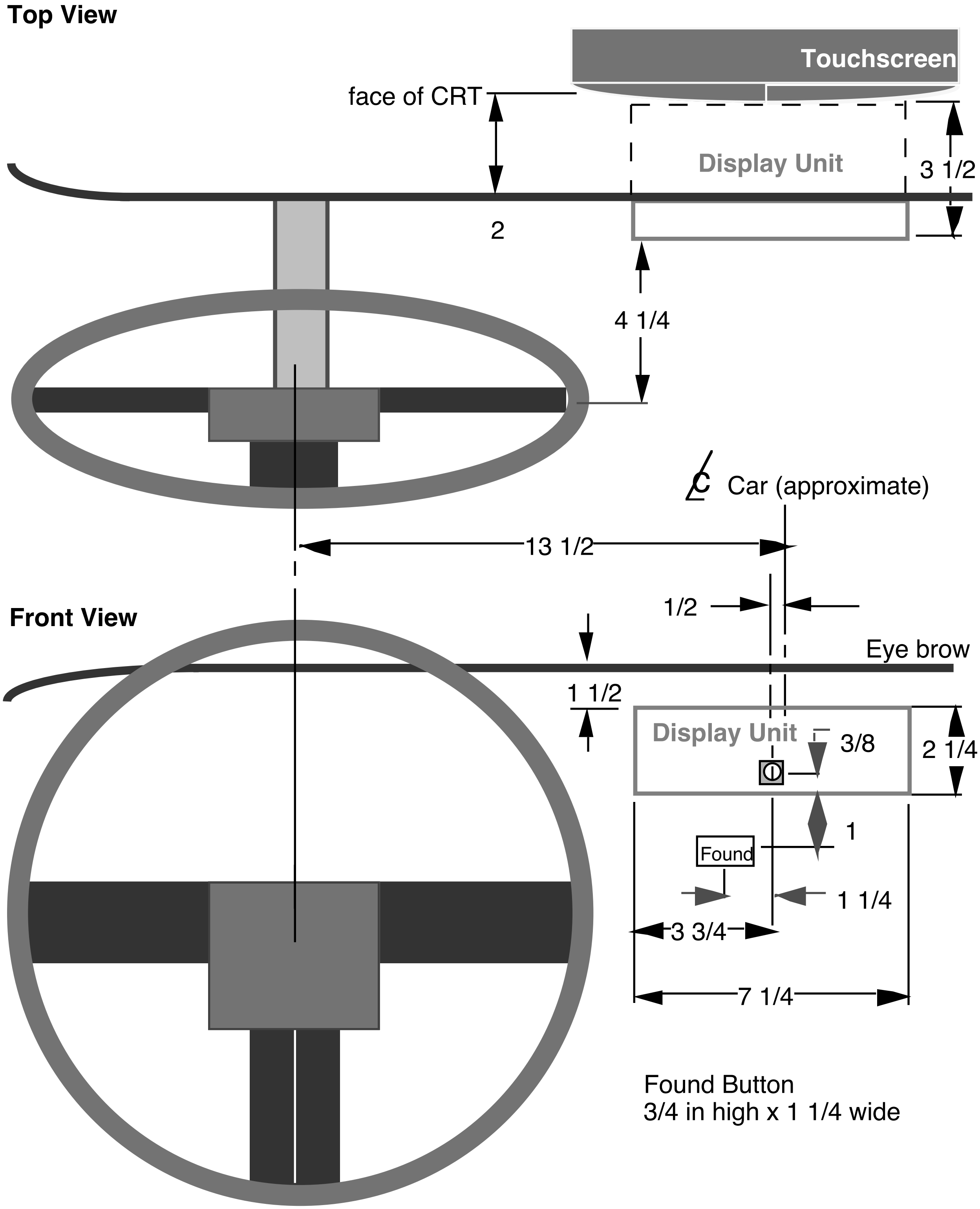
APPENDIX A - MEAN TASK TIMES FOR MOTOROLA PROTOTYPE 2

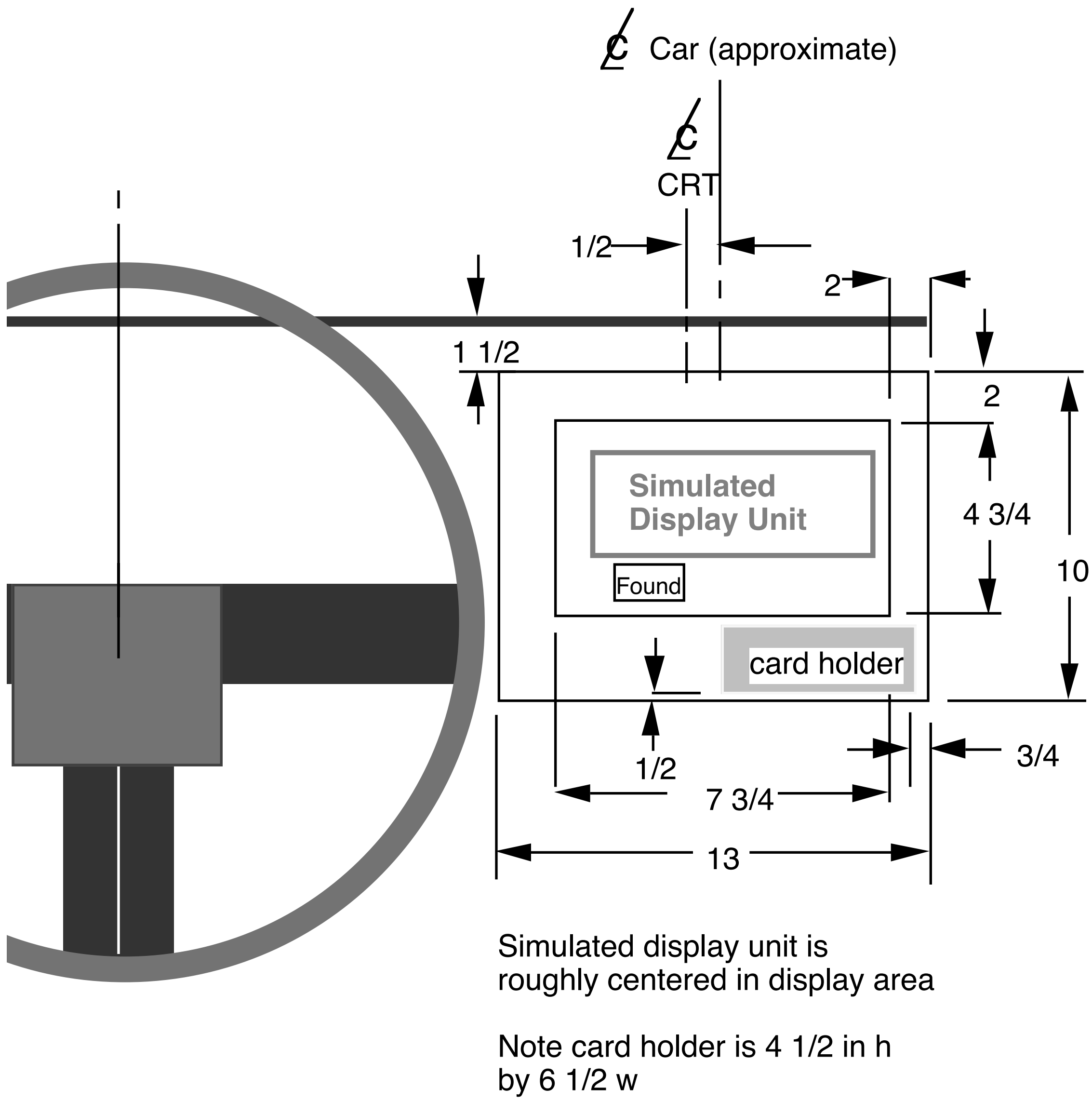
When	Task	Mean Time (s)
Exploration	find out what the system can do	5.75
	find out what the system thinks is the current address	20.14
	find out your current compass heading	4.22
	reset your present location to 0 Motorola Road. (specify the full address.)	117.33
	find out you current location on a map	12.56
	scroll the map down until you see Dundee Road	9.63
	zoom out until you can see Interstate 294 labeled	19.50
	change map view from N-up to heading-up (and back)	9.89
	display restaurants on the map	40.56
	find out where the nearest restaurant is	7.88
	find out the address of the nearest restaurant	72.33
	adjust the volume	32.75
Route Planning	set 542 Lindbert Lane as destination. Pick it from a map.	86.56
	Tell the device to plan a route to your destination	86.00
	find out how many miles you will drive on your route	25.44
	access another function of the device	32.25
	view your current location and your destination on the same map	8.44
	select "view from road" as the format for your route guidance	20.00
While Driving	get the next instruction	4.67
	find out how far it is to your next maneuver	2.29
	find out how far it is to your next destination	6.14
	turn the voice down	4.56
	find out how far you have driven since the beginning of your trip	51.75
	replan your route to avoid Doolittle	194.67
	save the trip plan you just drove	134.00
	correct a typographical error	1.00
Other Tasks	add yourself to the list of drivers	44.78
	modify your preferences by hiding the "What to Do" box	44.33
	change current driver to "Clark"	30.25
	recall the trip plan name "Sales Calls"	32.89
	add another leg to the trip plan "Sales Calls" 3450 Bayberry Rd, Northbrook	96.44
	Delete the first left from the trip plan "Sales Calls"	19.88
	Tailor the first leg by setting preference to min. distance	35.63
	get help on the task you are doing now	1.00
	delete the trip plan named "Steve's House"	67.78
	delete the driver name "Jon"	26.89

APPENDIX B - DISPLAY UNIT LOCATION



Location of Actual Ali-Scout unit

Note: Since the Ali-Scout display unit was mounted on a gooseneck and was moved aside periodically for other studies, the location varied slightly from subject to subject (plus or minus one inch).



Location of Simulated Display Unit (shown on CRT)

APPENDIX C - LIGHT LEVELS FOR THE EXPERIMENTAL CONDITIONS

		Illuminance (lux)	Character Location	Character Used	Character Color	Luminance (cd/m2)	
						Character	Background
Simulated	Dusk	31.8	door up	‹	white	15.10	1.00
			door dn	J	white	7.17	2.47
				O	yellow	7.40	2.47
				‹	white	9.83	1.83
			display	T	black	1.14	3.56
Real	Dusk	28.2	door up	‹	white	2.10	0.19
			door dn	J	white	1.03	0.24
				O	yellow	1.19	0.24
				‹	white	2.43	0.25
			display	T	black	2.03	3.03
	Night	14.7	door up	‹	white	0.86	0.06
			door dn	J	white	0.44	0.09
				O	yellow	1.30	0.09
				‹	white	1.30	0.15
			display	T	black	1.54	2.62

note: the T from the display is "at the starT"

APPENDIX D - BIOGRAPHICAL FORM

University of Michigan Transportation Research Institute
Human Factors Division

Subject: ☐

Biographical Form

Date: ☐

Name: ____________________________

Male Female (circle one) Age: ________________________

Occupation: ___________________________

Education (circle highest level completed):

some high school	high school degree
some trade/tech school	trade/tech school degree
some college	college degree
some graduate school	graduate school degree

Other: ____
(If retired or student, note it and your former occupation or major)

What kind of car do you drive the most?

Year: ______________ Make: ______________ Model: ______________

Annual mileage: _____________

Have you ever driven a vehicle with a navigation system? yes no

How comfortable are you using maps?

very comfortable | moderately comfortable | neutral | moderately uncomfortable | very uncomfortable

Have you ever used a touchscreen? yes no

How often do you use a computer?

never | less than once a month | a few times a month | a few times a week | every day

How comfortable are you typing (on a standard typewriter or computer keyboard)?

very comfortable | moderately comfortable | neutral | moderately uncomfortable | very uncomfortable

TITMUS VISION: (Landolt Rings)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
T	R	R	L	T	B	L	R	L	B	R	B	T	R
20/200	20/100	20/70	20/50	20/40	20/35	20/30	20/25	20/22	20/20	20/18	20/17	20/15	20/13

APPENDIX E - CONSENT FORM

Evaluation of Destination Entry and Retrieval
Participant Consent Form

In cars of the future, you may have an in-car navigation system which would tell you how to reach destinations. To use it, you'll need to tell the system where you want to go. We are looking at how to enter and retrieve these destinations for a navigation system. Responses from typical drivers such as you, will help improve this system.

While sitting in a vehicle mockup, you will respond to a simulated or a real navigation unit. By pressing buttons destinations can be entered or retrieved. A computer will record how long it takes to use the system. With your permission, we will videotape you. We will not record your face at any time. We will not release any identifying information, so your responses will remain confidential.

The experiment takes about 2 hours for which you will be paid $40. There will be opportunities for you to take a break if needed. If you have any problems completing this experiment, you can withdraw at any time. You will be paid regardless.

____

I have read and understand the information above.

______________________________ ______________________
Print your name Date

______________________________ ______________________
Sign your name Witness (experimenter)

It is OK to videotape me: yes no (circle one)

APPENDIX F - INSTRUCTIONS TO SUBJECTS

BEFORE SUBJECT ARRIVES

(Tavern)

- Highlight the current subject on the coordinate and entry/retrieval patterns
- Put the coordinate cards in order according to the coordinate pattern
- Put the entry/retrieval stacks in order according to the entry/retrieval pattern
- Open a new VHS tape and label it "Destination Entry Subject *## Date*"
- Turn on all audio/video equipment
- Insert and cue the Ali-Scout video
- Write all necessary information on the subject forms

(Sim Lab)

- Turn on the two computers
- Duct tape the Sim lab door so it doesn't lock
- Plug in the microphone
- Place the "road side" transparency and glare guard on the overhead
- Set up the car for either the touchscreen or Ali-Scout
- Lock the steering wheel
- Make a copy of the "ALISCOUT" file and rename the copy "DE.S##.R#.C*X#*"

INTRODUCTION

My name is ______ and I will be the person running the study today. If you have any problems completing this study, you can withdraw at any time. You will be paid regardless.

- Have the subject read the consent form along with you

In cars of the future, you may have an in-car navigation system which would tell you how to reach destinations. To use it, you'll need to tell the system where you want to go. We are looking at how to enter and retrieve these destinations for a navigation system. Responses from typical drivers such as you, will help improve this system.

While sitting in a vehicle mockup, you will respond to a simulated or a real navigation unit. By pressing buttons, destinations can be entered or retrieved. A computer will record how long it takes to use the system. With your permission, we will videotape you. We will not record your face at any time. We will not release any identifying information, so your responses will remain confidential.

- Have the subject fill out the consent and bio forms

PRACTICE

The first part of this study is a short learning period to become acquainted with the navigation unit. I have a tape for you to watch that will provide a brief introduction. Pay special attention to how the Ali-Scout works and how the shift key is used.

- Watch the Ali-Scout video
- Rewind and eject the tape
- Have the subject read the retrieval instructions
- Insert the subject tape
- **Push *Record***
- Turn off the big TV

For practice, please retrieve and enter the following sample destinations using the practice unit.

- Provide the practice sheet and paired manual

Dummy List	Retrieve List	Enter List		
		Location	Coordinates	
Amoco	BP Service	Cade Gallery	0830845W	422908N
Beckys Cafe	Firestone	Hunan Palace	0832531W	422805N
Echo Park Sch	Mayas Deli	Main Theater	0830840W	422926N
Siemens	Plus-Bank 24	Shell	0830532W	423534N
Star Deli	Subway	Village Market	0830901W	423715N

COORDINATE FINDING

To understand how people find coordinates for this navigation system, we are going to have you use the manual to find some navigation coordinates. We will be videotaping you from an angle that will not show your face. Please do <u>not</u> write in the manual.

- Run the coordinate finding series

Coordinate List

List	Format	Coordinates		
		red	blue	
	Ali-Scout Maps			
1	On Map 1, Giddings & Walton	0831540W	424040N	near middle
2	On Map 2, Auburn & Ryan	0830420W	423820N	1/2way to edge
3	On Map 3, Franklin & Maple	0831810W	423240N	bottom edge
	Address Ranges			
1	450 12 Mile Rd W.	0830635W	423017N	middle of range
2	2300 Coolidge Hwy.	0831101W	422939N	start
3	4429 Sashabaw Rd	0832212W	424211N	end
	Points of Interest			
1	Troy Union School	0830722W	423625N	
2	Glen Oaks Golf Course	0832116W	423050N	
3	Nicholas George Theater	0831425W	422803N	

- Eject the tape
- Turn off all audio/video equipment

Coordinate Pattern

Demographics			Coordinate Finding					
Subject	Sex	Age Group	Format Order			List Order		
1	F	1	M	A	P	1	2	3
2	F	1	P	M	A	3	1	2
3	F	1	A	P	M	2	3	1
4	F	2	M	A	P	3	1	2
5	F	2	P	M	A	2	3	1
6	F	2	A	P	M	1	2	3
7	F	3	M	A	P	2	3	1
8	F	3	P	M	A	1	2	3
9	F	3	A	P	M	3	1	2
10	M	1	M	A	P	3	1	2
11	M	1	P	M	A	2	3	1
12	M	1	A	P	M	1	2	3
13	M	2	M	A	P	2	3	1
14	M	2	P	M	A	1	2	3
15	M	2	A	P	M	3	1	2
16	M	3	M	A	P	1	2	3
17	M	3	P	M	A	3	1	2
18	M	3	A	P	M	2	3	1
19	F	1	M	A	P	1	2	3
20	F	1	P	M	A	3	1	2
21	F	1	A	P	M	2	3	1
22	F	2	M	A	P	3	1	2
23	F	2	P	M	A	2	3	1
24	F	2	A	P	M	1	2	3
25	F	3	M	A	P	2	3	1
26	F	3	P	M	A	1	2	3
27	F	3	A	P	M	3	1	2
28	M	1	M	A	P	3	1	2
29	M	1	P	M	A	2	3	1
30	M	1	A	P	M	1	2	3
31	M	2	M	A	P	2	3	1
32	M	2	P	M	A	1	2	3
33	M	2	A	P	M	3	1	2
34	M	3	M	A	P	1	2	3
35	M	3	P	M	A	3	1	2
36	M	3	A	P	M	2	3	1

MAIN EXPERIMENT

We will now move on to the next part of the study.

- Walk the subject to the Sim Lab
- Turn on the power strip of the sound cart and push *2, 3, eff,* and *autotake*
- Insert the tape
- **Push *record***
- Make sure the counter is advancing and the picture is clear
- Turn on the overhead and PC projector

- --> Set up the car for the next block according to the pattern list (where "Light" = sunroof and dashboard lights and "Dark" = headliner light)
- Have the subject get in the car and (if necessary) show him how to adjust the seat

Just before using the simulated Ali-Scout

- Run the Touchscreen control panel and have the subject calibrate the touchscreen
- Run Touchscreen Trainer to make sure the calibration was correct
- Put the frame on the touchscreen
- Open the simulation program and fill in the appropriate information (output file = DE.S*##*.R*#*.C*X#*)

- **Turn off the room lights**

When I hand you a card, please use the system to <u>find</u> the location listed on the card. When you have found it please press the "FOUND" key then the cancel key (the X'd circle) and put the card in the envelope. I will then give you another card. Do you have any questions? Please turn on the system.

- Run the retrieval series

The next phase involves entering some locations into the unit. When I hand you a card, <u>enter</u> the information listed on it. When you have finished entering the information into the unit, please press the "FOUND" key and put the card in the envelope. Do you have any questions? Please turn on the system.

- Run the entry series
- Have the subject hand you the cards from the envelope
- Have the subject close the door and turn off the Ali-Scout
- Sort the cards
- Turn on the room lights
- If necessary, have the subject step out of the car

- Clear all unwanted destinations from the Ali-Scout and select “AT THE START” as the current destination <u>or</u> quit the simulator -->

Retrieval Lists

A	B	C	Dummy
Sakura Bank	Seafood Bay	Bill Knapps	Montgmry Ward
Bir Ice Arena	Print Gallery	Primos Pizza	Royal Oak Deli
Monterrey Rest	Majestic Cafe	Woodside Hosp	Sears
Mobil	Vandenburg Sch	Bir Theater	Bir Art Gallry
Big Boy	Bir Library	Mongolian BBQ	Palace of AH

Entry Lists

Set	Name	Coordinates	
A	Nicks Place	0831732W	423814N
	Q Gas	0831654W	424038N
	Helens Kitchen	0831649W	424002N
	Yaw Gallery	0831303W	423302N
	Goodyear	0830508W	423006N
B	Farmer Jack	0830937W	423159N
	Taco Loco	0831932W	423750N
	First of Am	0832459W	424307N
	Jacobsons	0830905W	424054N
	Chevron	0831707W	423032N
C	Lark Rest	0832250W	423236N
	Unicorn Grill	0830848W	422919N
	Krogers	0830506W	422923N
	Qwik Stop	0832353W	423936N
	Tuffy Auto	0831642W	422737N
Dummy	Licht Park	0830731W	423051N
	Nordstrom	0831211W	422959N
	Discafe	0831732W	423814N
	Oakland Mall	0830638W	423203N
	Olive Garden	0830828W	423047N

- Rewind and eject the tape
- Turn off the power strip of the audio cart
- Turn off the touchscreen, car lights, overhead projector, and PC projector

Entry/Retrieval Pattern

Demographics			Destination Retrieval/Entry Blocks		
Subject	Sex	Age Group	1 (Cards)	2 (Cards)	3 (Cards)
1	F	1	Sim (A)	Dark (C)	Light (B)
2	F	1	Light (C)	Sim (B)	Dark (A)
3	F	1	Dark (B)	Light (A)	Sim (C)
4	F	2	Sim (B)	Light (C)	Dark (A)
5	F	2	Dark (C)	Sim (A)	Light (B)
6	F	2	Light (A)	Dark (B)	Sim (C)
7	F	3	Sim (C)	Dark (B)	Light (A)
8	F	3	Light (B)	Sim (A)	Dark (C)
9	F	3	Dark (A)	Light (C)	Sim (B)
10	M	1	Sim (C)	Light (A)	Dark (B)
11	M	1	Dark (A)	Sim (B)	Light (C)
12	M	1	Light (B)	Dark (C)	Sim (A)
13	M	2	Sim (B)	Dark (A)	Light (C)
14	M	2	Light (A)	Sim (C)	Dark (B)
15	M	2	Dark (C)	Light (B)	Sim (A)
16	M	3	Sim (A)	Light (B)	Dark (C)
17	M	3	Dark (B)	Sim (C)	Light (A)
18	M	3	Light (C)	Dark (A)	Sim (B)
19	F	1	Sim (A)	Dark (C)	Light (B)
20	F	1	Light (C)	Sim (B)	Dark (A)
21	F	1	Dark (B)	Light (A)	Sim (C)
22	F	2	Sim (B)	Light (C)	Dark (A)
23	F	2	Dark (C)	Sim (A)	Light (B)
24	F	2	Light (A)	Dark (B)	Sim (C)
25	F	3	Sim (C)	Dark (B)	Light (A)
26	F	3	Light (B)	Sim (A)	Dark (C)
27	F	3	Dark (A)	Light (C)	Sim (B)
28	M	1	Sim (C)	Light (A)	Dark (B)
29	M	1	Dark (A)	Sim (B)	Light (C)
30	M	1	Light (B)	Dark (C)	Sim (A)
31	M	2	Sim (B)	Dark (A)	Light (C)
32	M	2	Light (A)	Sim (C)	Dark (B)
33	M	2	Dark (C)	Light (B)	Sim (A)
34	M	3	Sim (A)	Light (B)	Dark (C)
35	M	3	Dark (B)	Sim (C)	Light (A)
36	M	3	Light (C)	Dark (A)	Sim (B)

CONCLUSION

The data entry tasks are completed. I would now like to check your eyesight.

- Make sure eyesight condition is the same as when testing was done
- Test the subject's eyesight

We will now go back to the office to fill out some final forms.

- Walk the subject back to the office

Please fill out this question sheet. If you have additional comments please use the space provided.

- Have the subject fill out the question sheet

Please fill out this form so that I can pay you.

- Have the subject fill out the payment form
- Walk the subject towards the stairs
- Pay the subject

Before you go, I would like to measure your finger size so that I can evaluate the size and placement of the buttons on the navigation unit.

- Walk the subject to the copy room
- Make a copy of the subject's finger using the cardboard with plastic window

AFTER SUBJECT LEAVES

(Sim Lab)

- Unplug the microphone
- Turn off the two computers
- Remove the duct tape from the door

(Tavern)

- Clear all unwanted destinations from the Ali-Scout and select "AT THE START" as the current destination
- Cross off the current subject on the coordinate and entry/retrieval patterns
- Lock the door and return the key to the desk

(343B)

- Staple all the paperwork and put it in the file

APPENDIX G - EXPERIMENTAL DETAILS

Coordinate Search Task Counterbalancing

Subject	Sex	Age	Format Order			List Order		
1	F	young	M	A	P	1	2	3
2	F	middle	P	M	A	3	1	2
3	F	old	A	P	M	2	3	1
4	F	young	M	A	P	3	1	2
5	F	middle	P	M	A	2	3	1
6	F	old	A	P	M	1	2	3
7	F	young	M	A	P	2	3	1
8	F	middle	P	M	A	1	2	3
9	F	old	A	P	M	3	1	2
10	M	young	M	A	P	3	1	2
11	M	middle	P	M	A	2	3	1
12	M	old	A	P	M	1	2	3
13	M	young	M	A	P	2	3	1
14	M	middle	P	M	A	1	2	3
15	M	old	A	P	M	3	1	2
16	M	young	M	A	P	1	2	3
17	M	middle	P	M	A	3	1	2
18	M	old	A	P	M	2	3	1

repeat for 19-36

Note: Format order codes are:

P—Points of Interest (given the name, find the coordinates in a list),
A—Address Ranges (given an address, find the coordinates in a list)
M—Ali-Scout Maps (given two intersecting roads, find the coordinates on a map).

List order is a code for what subjects saw in the first, second, and third blocks.

Balancing Outcome for the Entry Tasks

	Average	
	# Keystrokes	# Shifts
1st Location	11.3	1.0
2nd Location	10.0	1.0
3rd Location	10.5	0.8
4th Location	11.3	1.0
5th Location	10.3	1.0
A	10.8	1.0
B	10.4	1.0
C	10.6	1.0
Dummy	10.8	0.8
Overall	10.7	1.0

Counterbalanced Sequence for Conditions

Demographics			Block Order with Conditions		
Subject	Sex	Age Group	1 (Set)	2 (Set)	3 (Set)
1	F	1	Sim (A)	Night (C)	Dusk (B)
2	F	1	Dusk (C)	Sim (B)	Night (A)
3	F	1	Night (B)	Dusk (A)	Sim (C)
4	F	2	Sim (B)	Dusk (C)	Night (A)
5	F	2	Night (C)	Sim (A)	Dusk (B)
6	F	2	Dusk (A)	Night (B)	Sim (C)
7	F	3	Sim (C)	Night (B)	Dusk (A)
8	F	3	Dusk (B)	Sim (A)	Night (C)
9	F	3	Night (A)	Dusk (C)	Sim (B)
10	M	1	Sim (C)	Dusk (A)	Night (B)
11	M	1	Night (A)	Sim (B)	Dusk (C)
12	M	1	Dusk (B)	Night (C)	Sim (A)
13	M	2	Sim (B)	Night (A)	Dusk (C)
14	M	2	Dusk (A)	Sim (C)	Night (B)
15	M	2	Night (C)	Dusk (B)	Sim (A)
16	M	3	Sim (A)	Dusk (B)	Night (C)
17	M	3	Night (B)	Sim (C)	Dusk (A)
18	M	3	Dusk (C)	Night (A)	Sim (B)

repeat for 19-36

APPENDIX H - PRACTICE SHEET

Please find the following locations in the order they are shown. Press the **FOUND** button after finding each one.

BP SERVICE

FIRESTONE

MAYAS DELI

PLUS-BANK 24

SUBWAY

Please enter the following locations and their coordinates in the order shown.

Location	Coordinates	
CADE GALLERY	0830845W	422908N
HUNAN PALACE	0832531W	422805N
MAIN THEATER	0830840W	422926N
SHELL	0830532W	423534N
VILLAGE MARKET	0830901W	423715N

APPENDIX I - RETRIEVAL DATABASE

Location	Group	Type	Scroll	Hybrid	Min
AT THE START		1	0	1	0
BIG BOY	A	3	**2**	2	**2**
BILL KNAPPS	C	3	**3**	3	**3**
BIR ART GALLRY	D	5	**4**	4	**4**
BIR ICE ARENA	A	5	**5**	5	**5**
BIR LIBRARY	B	5	**6**	6	5
BIR THEATER	C	5	**7**	7	5
MAJESTIC CAFE	B	2	**8**	2	2
MOBIL	A	3	**9**	3	3
MONGOLIAN BBQ	C	4	**10**	4	4
MONTERREY REST	A	5	**11**	5	5
MONTGMRY WARD	D	5	**12**	6	5
PALACE OF AH	D	3	**13**	2	2
PRIMOS PIZZA	C	4	**14**	3	3
PRINT GALLERY	B	4	**15**	4	4
ROYAL OAK DELI	D	1	**16**	1	1
SAKURA BANK	A	2	**17**	2	2
SEAFOOD BAY	B	4	**18**	3	3
SEARS	D	4	**19**	4	4
VANDENBURG SCH	B	1	**20**	1	**2**
WOODSIDE HOSP	C	1	**21**	1	1

Note: The scroll and min columns are fixed. To enter the scroll mode, an arrow key must be pressed.

APPENDIX J - DISPLAY UNIT POST-TEST QUESTIONNAIRE

Please place a check in the appropriate box for each question. There is additional room for comments, if needed.

1. Are the keys the right size?

	too small	just right	too large
Simulated			
Real			

2. Is the spacing between the keys the right size?

	too small	just right	too large
Simulated			
Real			

3. Is the text on the display the right size?

	too small	just right	too large
Simulated			
Real			

4. Does the screen have the right amount of contrast?

	not enough	just right	too much
Simulated			
Real			

5. Does the system behave in a logical manner?

	no	yes
Simulated		
Real		

APPENDIX K - ANOVA TABLES

ANOVA summary table for destination retrieval time.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Sex	1	1280.602	1280.602	7.769	.0055
Age Group	2	10027.110	5013.555	30.414	.0001
Sex * Age Group	2	1078.592	539.296	3.272	.0388
Subject (Sex, Age Group)	30	15078.253	502.608	3.049	.0001
Residual	504	83080.785	164.843		

ANOVA summary table for destination entry time.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Sex	1	17696.433	17696.433	16.726	.0001
Age Group	2	230400.068	115200.034	108.882	.0001
Sex * Age Group	2	5009.592	2504.796	2.367	.0948
Subject (Sex, Age Group)	30	220173.228	7339.108	6.937	.0001
Residual	504	533244.526	1058.025		

ANOVA summary of lighting condition effect and some interactions for destination retrieval. The dependent variable is retrieval time (dusk and night only).

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject (Sex, Age Group)	32	7196.522	224.891	2.503	.0001
Condition	1	111.690	111.690	1.243	.2657
Sex	1	316.444	316.444	3.522	.0615
Age Group	2	3433.222	1716.611	19.103	.0001
Condition * Sex	1	1.840	1.840	.020	.8863
Condition * Age Group	2	44.363	22.182	.247	.7814
Residual	320	28755.190	89.860		

ANOVA summary of lighting condition effect and some interactions for destination entry. The dependent variable is entry time (dusk and night only).

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject (Sex, Age Group)	32	107579.594	3361.862	4.984	.0001
Condition	1	12267.156	12267.156	18.186	.0001
Sex	1	18328.816	18328.816	27.172	.0001
Age Group	2	154795.652	77397.826	114.742	.0001
Condition * Sex	1	939.898	939.898	1.393	.2387
Condition * Age Group	2	15874.079	7937.039	11.767	.0001
Residual	320	215852.002	674.538		

ANOVA summary of condition effect and some interactions
for destination retrieval. The dependent variable is retrieval time.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject (Sex, Age Group)	32	16156.845	504.901	3.322	.0001
Condition	2	5098.057	2549.029	16.773	.0001
Sex	1	1280.602	1280.602	8.427	.0039
Age Group	2	10027.110	5013.555	32.990	.0001
Condition * Sex	2	393.767	196.883	1.296	.2747
Condition * Age Group	4	2211.261	552.815	3.638	.0062
Residual	496	75377.700	151.971		

ANOVA summary of condition effect and some interactions
for destination entry. The dependent variable is entry time.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
Subject (Sex, Age Group)	32	225182.820	7036.963	7.380	.0001
Condition	2	37178.876	18589.438	19.495	.0001
Sex	1	17696.433	17696.433	18.559	.0001
Age Group	2	230400.068	115200.034	120.814	.0001
Condition * Sex	2	3089.331	1544.665	1.620	.1990
Condition * Age Group	4	20026.051	5006.513	5.251	.0004
Residual	496	472950.268	953.529		