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Usability of Text, Graphic, and Video In-Car Traffic Information for Diversion Decisions

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16. Abstract

This experiment examined how in-car traffic information should be presented so it is easy to use. Twelve young drivers operated an instrumented car on an expressway. Concurrently they were periodically shown a skeleton map of two alternative routes on a 5.5-inch LCD display. Drivers then pressed a button to show details of the first route for 10 seconds. Subsequently, they pressed a button to see the alternative route. Finally, they pressed a button for the route with the shortest travel time. After 10-20 seconds the process was repeated, for a total of 16 trials.

Four display formats were examined: text (typically 5 lines showing the route number, the beginning and end points of the blockage, speed, and the delay time), graphic (showing speed and a color-coded detail of the road segment), still video (1 frame), and moving video (up to 10 seconds). The video scenes were taken from overhead cameras operated by the expressway traffic control center in Detroit.

The ordering of format across performance measures was consistent--text was best, followed by graphic, then still video, and then motion video. Text had the shortest fixation times, the smallest number of fixations, the briefest response times, and was preferred by drivers.

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Introduction

Motorists often face traffic-related delays in their daily travel. Delays resulting from congestion are extremely costly--about $31.8 billion dollars each year for the 12 largest cities in the U.S. (Mobility 2000, 1990). (See also, Serafin, Williams, Paelke, and Green, 1991). These expenses are derived from lost time, excess fuel use, and other direct costs. Congestion also leads to increased air pollution, resulting from additional vehicle hours and stop-and-go driving. Efforts to reduce travel delay are being made through the development of Intelligent Vehicle-Highway Systems (IVHS), including the Advanced Traveler Information Systems (ATIS), which can assist motorists by providing traffic information to avoid potential delays.

The benefits of providing traffic information to travelers depend on how effectively that information is conveyed. The information will likely be received while driving (possibly during peak-period traffic). Therefore, it is essential for drivers to attain and understand the traffic information messages quickly and easily. Consideration must be given to the content of the messages, their format, the presentation mode, and other related issues. Essentially, the traffic information must be provided in a manner that is effectively received without distracting from the primary task of driving.

Recent research efforts have addressed some of these issues. In the Seattle, Washington area, an extensive survey was conducted to determine what effects providing traffic information could have on travelers' use of alternate routes (Haselkorn and Barfield, 1990). Over 9500 surveys were distributed to motorists along freeway exits during peak morning travel. A total of 3893 surveys were returned and analyzed. The survey indicated males were 10% more likely than females to change their home-work routes. Of those responding, 28% said they used traffic reports and messages "frequently" and another 48% said they use those messages "sometimes." Enroute traffic information either "frequently" or "sometimes" caused 52% to divert to an alternate route. A factor analysis indicated that the effectiveness of information systems on commuter behavior depends on the distance traveled, time available, knowledge of routes, and personal characteristics of drivers.

A second survey was given to 98 of the original participants. Static representations of five traffic information screens were shown. The contents of each screen are shown in Figure 1. (Screen 2 was used as a control and showed very light traffic conditions.) Screen 5, showing a still video picture with travel time estimates, was chosen by 56% to be the most helpful screen for route planning. It was preferred based on the amount of information and travel time estimates provided.

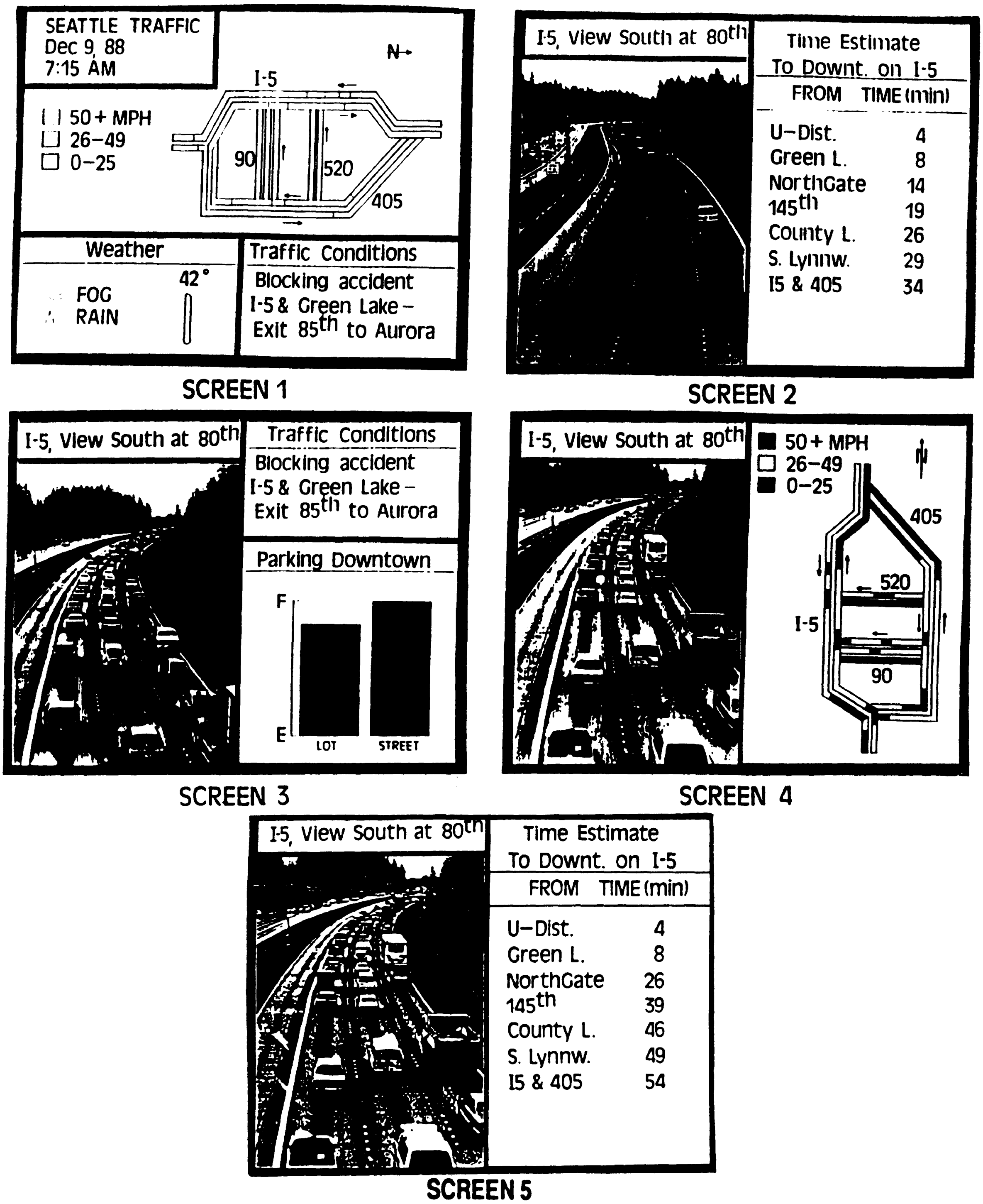


Figure 1. Potential traffic information screens for Seattle, Washington (Haselkorn and Barfield, 1990).

Participants also ranked the helpfulness of five forms of information for their route planning. Time estimates were preferred overall, as indicated in Table 1.

Table 1. Helpfulness of various types of information

Rank (1=most helpful)	Information
1.79	Time estimates
2.32	Text messages
2.86	Photos of actual traffic conditions
3.17	Color coded maps
4.51	Bar graphs

Traffic information was preferred in text or numeric form. It should be noted that this preference data is based upon impressions from seeing pictures of the screens in a laboratory, not from actually using the information while driving.

Allen, Stein, Rosenthal, Ziedman, and Halati (1991) examined the effect of in-vehicle navigation display formats on driver route diversion using a laboratory simulation. A total of 277 drivers (62 commercial and 215 noncommercial) participated in the study. Each driver used 1 of 4 navigation display formats: 1) static map (showing vehicle location on an electronic map); 2) dynamic map (location and color-coded roads indicating congestion levels); 3) advanced map (dynamic plus status of traffic, cause, delay, and arrival time); and 4) route guidance (explicit turn guidance, expected arrival time, distance to destination).

The study involved viewing successive slides of a driver's-eye view of an expressway. The slides showed the current speed of the vehicle and traffic density. Participants used the slides along with the navigation system to make diversion decisions. Three levels of delay were used: 11, 18, and 30 minutes.

The effectiveness of the display format was determined by how soon (upstream of the traffic problem) drivers diverted from the highway. Drivers diverted soonest when using the route guidance and advanced guidance displays. The static display (no congestion information) resulted in similar behavior to the control group (no guidance at all). Drivers diverted much sooner when they knew the delay was long (30 minutes). The route guidance and advanced displays were much more effective for getting people to divert for the 11-minute-delay scenario. The results showed that average travel speed was important in drivers' decisions to divert.

The approach of Allen, Stein, Rosenthal, Ziedman, and Halati went beyond the scope of Haselkorn and Barfield by providing functional displays and a simulated highway environment to participants. However, it is also necessary to look at the effects of displaying traffic information to people while they actually drive. The present study was conducted to address which format of traffic information is most effective for people to use while driving. Furthermore, it considers real time video, which has not been examined to date.

For the present experiment, prototypes of four visual traffic information systems were developed: 1) moving video (actual videotaped segments of traffic moving on the highway taken from an aerial view); 2) still video (a single frame of that video footage); 3) graphic (a color-coded graphic of the highway used to indicate travel speed); and 4) text (traffic information provided in a concise text message).

Drivers used each system while wearing an eye mark camera (that recorded eye gaze direction) and driving an instrumented vehicle on an expressway. The following questions were addressed:

- Which form of traffic information is least distracting (as measured by the number and duration of eye fixations)?
- Which interface design requires the least amount of time to use (as measured by response time)?
- Which interface minimizes decision errors?
- Which interface is preferred by drivers?
- How much are drivers willing to pay for these systems?

Test Plan

Overview

All participants were presented traffic information on an in-vehicle display shown four ways: skeleton (graphic) maps, text, and both motion video and still video recorded images of roads. In all four cases, the participants were first presented a skeleton map showing two routes (A and B) that could be taken to reach a predetermined destination. One traffic problem was shown on each alternative route, indicated by a color-coded segment (red or yellow, depending on the severity of the problem). Under normal conditions, these alternative routes were considered equal in road condition, distance, and travel time.

After viewing the introductory screen showing both routes, participants retrieved more detailed traffic information for each of the individual routes by pressing corresponding buttons located just below the display. Based on the traffic information presented, participants selected a preferred route by pressing a corresponding button.

Participants walked through a practice session of each of the four interfaces while wearing the uncalibrated eye mark camera and sitting in the driver's seat of the stationary test vehicle. Later, they were presented the same practice session, without the eye camera, while driving out to the test route. Finally, data were collected for the test trials while wearing the calibrated eye camera and driving. Participants did not actually drive to the destination, but were asked to pretend they were approaching the route decision point shown on the first screen while driving the test route.

Later, subjects made estimates of the speed of traffic for each of the moving video presentations, ranked the four systems in terms of ease of use, and stated if they would buy any of the systems, as well as how much they would be willing to pay for them.

Test Participants

Twelve young (19-25 years old, mean=22) licensed drivers participated in this experiment, six women and six men. Older drivers were not included due to the weight, and possible discomfort, of wearing the eye mark camera. Participants' corrected visual acuities ranged from 20/40 to 20/13, using a Titmus Vision Tester. Six participants wore glasses or contacts during the study. Participants were friends of the experimenters, were recruited through a notice posted on a University of Michigan electronic conference, or were contacted from lists of participants from previous studies. They were paid $25 for approximately two hours of their time.

Participants reported that they drove from 2,000 to 25,000 miles per year (mean = 11,600 miles). Eight of the participants stated that they were very comfortable using maps, while four stated that they were moderately comfortable using maps. In the last six months, they had used a map an average of six times each. Also, seven participants were very familiar with metro Detroit highways while five were either moderately or very unfamiliar with that area. None of the subjects owned cars with a head-up display (HUD), nor had they ever driven a car with a HUD or a navigation system.

Test Equipment and Materials

Test vehicle

Data was collected using a modified 1991 Honda Accord LX station wagon with an automatic transmission. Figure 2 displays the instrumentation and layout of the test vehicle. The station wagon is very similar to the Accord sedan which is the most commonly purchased new car in the U.S.

The following instrumentation was installed in the test vehicle. All sampling was done at 30 Hertz.

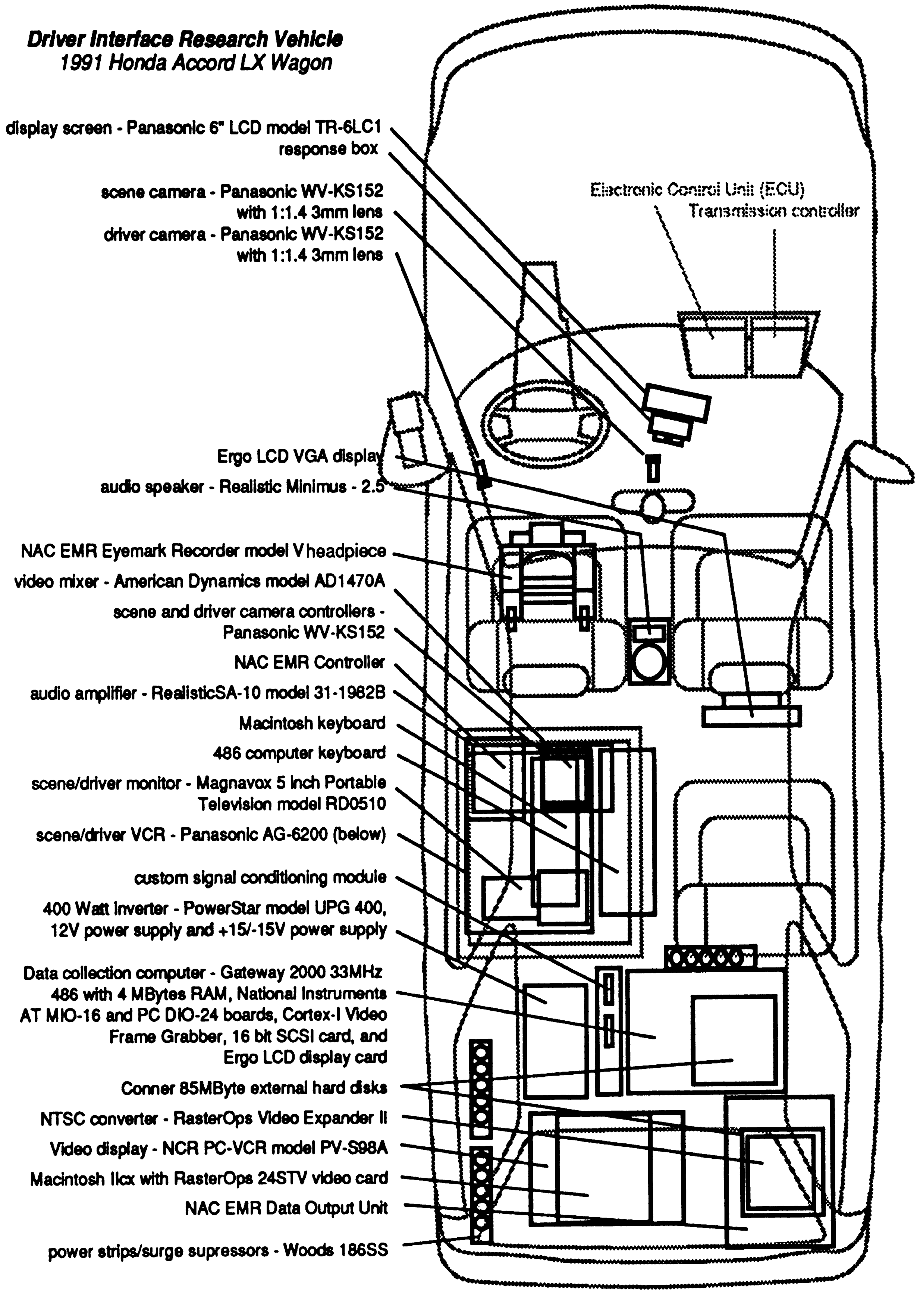
Road Scene - Mounted in front of the inside mirror and facing forward was a thumb-sized color camera. The video was merged with video from another camera via a signal splitter and recorded on a VCR. Output from this camera was collected during the on-the-road practice session.

Driver Movement- Mounted on the left A pillar and facing the driver was a second thumb-sized color camera. For this experiment, a wide-angle lens was used, enabling a view of the subjects' upper torso, showing some driver movement and control operations. This video was merged with video from the road scene camera, and recorded on the VCR during the on-the-road practice.

Eye Gaze Direction - In this study, drivers wore a NAC EMR model V eye-fixation recorder. The system provided analog output for eye fixation coordinates accurate to the nearest degree. Direction of gaze could be recorded by Eye Mark Recording units from either side of the head piece, which are driven by the NAC Camera Controller. This output was recorded on the 486 computer. Data were collected for the right eye only during the on-the-road test sequence, due to the complexity of calibrating the eye marks. Since both eyes move together, the gaze direction of one eye is sufficient. The eye-fixation system did not have a head position sensor.

Drivers' View - Participants' viewing area was recorded from a camera in the forehead area of the EMR head piece. The eye fixations for the right eye only were shown overlaid on the participants' scene, and were recorded on the VCR during the test sequence only. The coordinates of the fixations were recorded by the 486. Both streams were synchronized. The data collection software did not provide for real-time display of all data streams during data collection. However, the software can provide summary statistics on demand and allows for the entry of time-stamped comments via the keyboard at any time. In this configuration, data could be collected for about 24 minutes before it had to be saved to disk. To permit correlation of vehicle and driver performance with the navigation display, the Macintosh IIcx and the 486 communicated timing data via an RS-232 serial link.

Driver Interface Research Vehicle
1991 Honda Accord LX Wagon



Most of the major pieces of equipment (computers, power conditioners, etc.) were hidden from view in the back seat by tinted window shades, or in the cargo area which had its own retractable vinyl cover. From the outside, the instrumented car looked like a normal station wagon. During the study, however, an "UMTRI Test Vehicle" sign was fastened to the trunk door to discourage tailgating and other aggressive driving which could present a hazard to the test vehicle occupants. When the eye camera was worn by the driver, it was obvious and noticed by other motorists.

All of the displays the participants saw were presented on a Panasonic (model TR-6LC1) 6-inch diagonal color LCD monitor. The monitor is sold only in Japan and is used as an in-car TV screen. A RasterOps 24STV connected to a Video Expander II converted the 640-480 Mac output into NTSC for the LCD display. The monitor was mounted in the center console area just to the right of the climate control unit. Figure 3 shows its location, and the response box buttons.

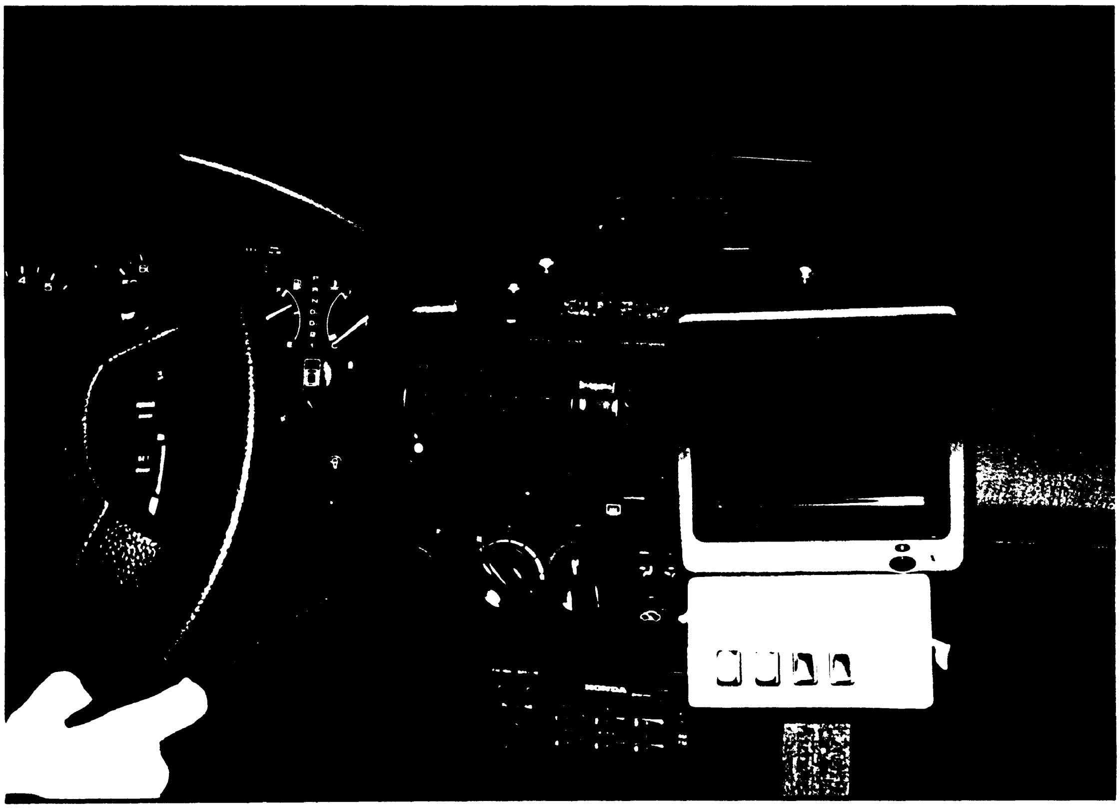


Figure 3. Picture of the Test Car Interior.

Text and graphic displays were generated in Adobe Illustrator on a Macintosh computer. Static and dynamic video displays were taken from videotapes recorded using cameras connected to Surveillance Control and Driver Information Systems (SCANDI), the traffic monitoring center in Detroit run by the Michigan Department of Transportation. The displays were recorded on videotape and presented by an NEC PC-VCR under the control of a Macintosh IIcx. A program written in HyperTalk controlled the display of screens and the PC-VCR.

Introductory screen (Showing routes A and B)

The introductory screens were skeleton maps displaying general information on traffic problems (speed of traffic, and location of the affected area) along the two possible routes to the destination. The vehicle location and the destination were also shown by an arrow and a star, respectively. A sample introductory screen is shown in Figure 4.

The major roadways and interchanges between the vehicle and the destination were labeled and indicated with colored lines. Gray lines, labeled A or B, indicated the respective routes. Each side of the road (direction of traffic) was indicated with a colored line; areas of the highway that were affected by traffic problems were shown as red or yellow segments. Yellow indicated traffic that was flowing slowly (between 30 and 50 mph) in that area, and red indicated very slow or crawling traffic (under 30 mph). Black lines represented the median between the sides of the highway. Normal traffic conditions were shown as green segments, where the normal urban speed limit was 55 mph. Although it was not shown on the display, north was up.

Detailed route interfaces (for individual route information)

After an introductory screen was presented, detailed traffic information screens for each route were displayed to all participants in four formats: graphic (skeleton) screens, still video screens, text screens, and moving video screens. Participants saw four trials in a row in the same format for each of the four formats. They always made route choices based on traffic information they received from pairs of screens in the same format. All speed differences were 10 mph for text and graphic screens and 10 mph +/-2 mph for still and moving video.

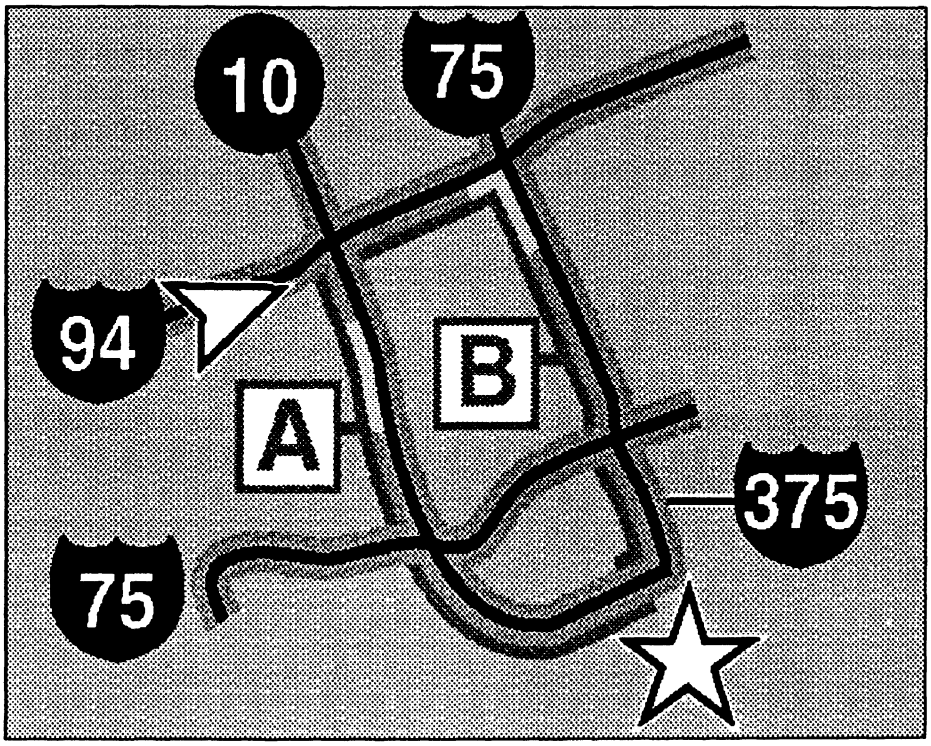


Figure 4. Introductory screen showing two possible routes (A and B).
Note: The arrow indicates the current vehicle location, the star its destination.
General traffic information is color coded.

Graphic screens

The graphic (skeleton) screens were map-like representations showing a more detailed view of the area of the road with a traffic problem. This format was comparable to that of the introductory screen. Figure 5 presents a sample graphic screen. The affected area of the road was shown in the same orientation as was displayed in the introductory screen (north being up). Major and minor cross-streets, interchanges, and the speed of traffic (mph) in that area were also shown.

Text screens

The text screens contained slightly different information, depending on the nature of the traffic problem (i.e., congestion, or accident). A text screen could contain the following detailed traffic information about the affected area: nature of the problem, its location (starting and ending points), its length (miles), speed of traffic (mph) and estimated length of the delay (minutes). A sample screen is shown in Figure 6.

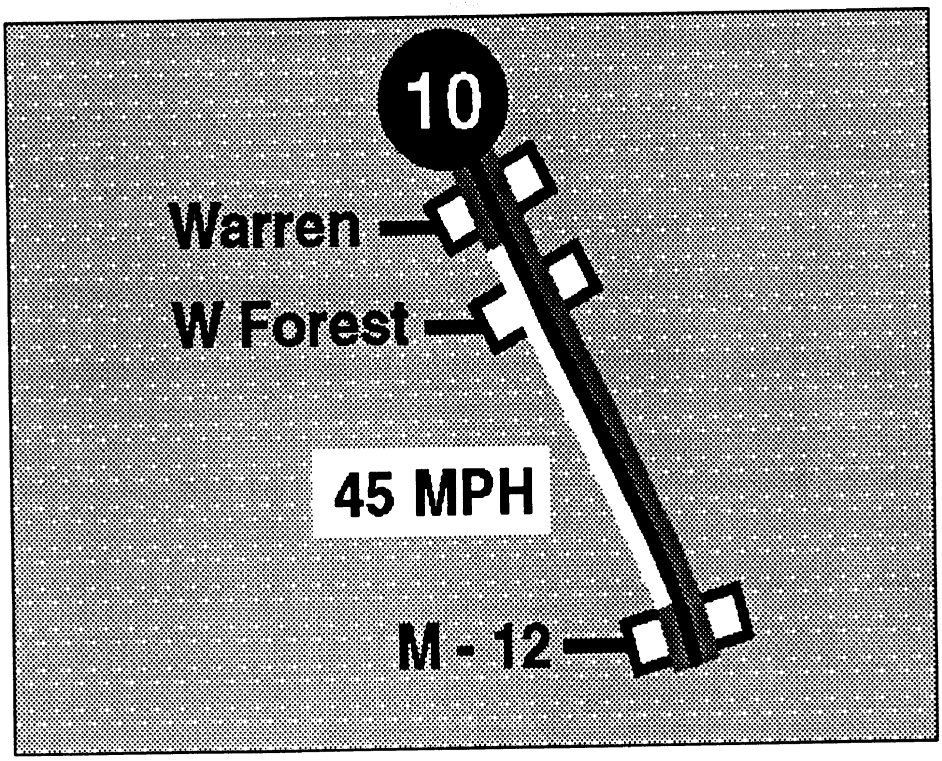


Figure 5. Graphic screen showing detailed information
(speed of traffic and location of affected area) for one route.

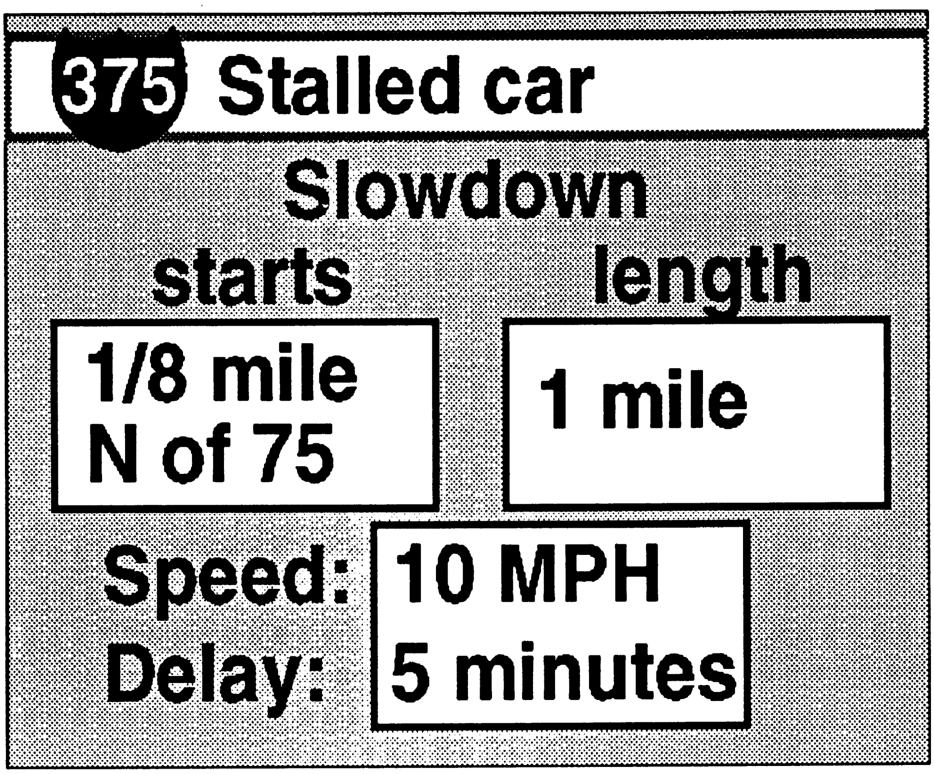


Figure 6. Text screen for one of the routes.

Still video screens

The still video screens were static images from a recorded videotape of actual highway traffic taken from video cameras located along Interstate-94 between Ann Arbor and downtown Detroit, MI. Interstate-94 is a six-lane, divided highway with moderate to heavy traffic leading into metropolitan Detroit. These images were recorded by SCANDI on various buildings and overpasses along the road, on July 15, 1992, between 4:30 and 6:30 PM. Speeds were determined from the videotape by counting the number of frames required for a car to travel from one section of a lane marker to the next for three cars in each lane. Based on lane marker distances, the speeds were computed and averaged. Still scenes were paired so the differential in speed was as close to 10 mph as possible. The same was done for moving video. Identical scenes were not shown for both still and moving video. Although it was not visible on the videotape, it was raining lightly during the recording.

Figure 7 presents a sample still video screen. These screens contained a red or yellow segment along the shoulder of the affected side of the road. Color coding of the traffic speed here was consistent with the introductory screen. (Since only problematic areas of the roadway were shown on the detailed information screens, there were never green segments in these screens.)

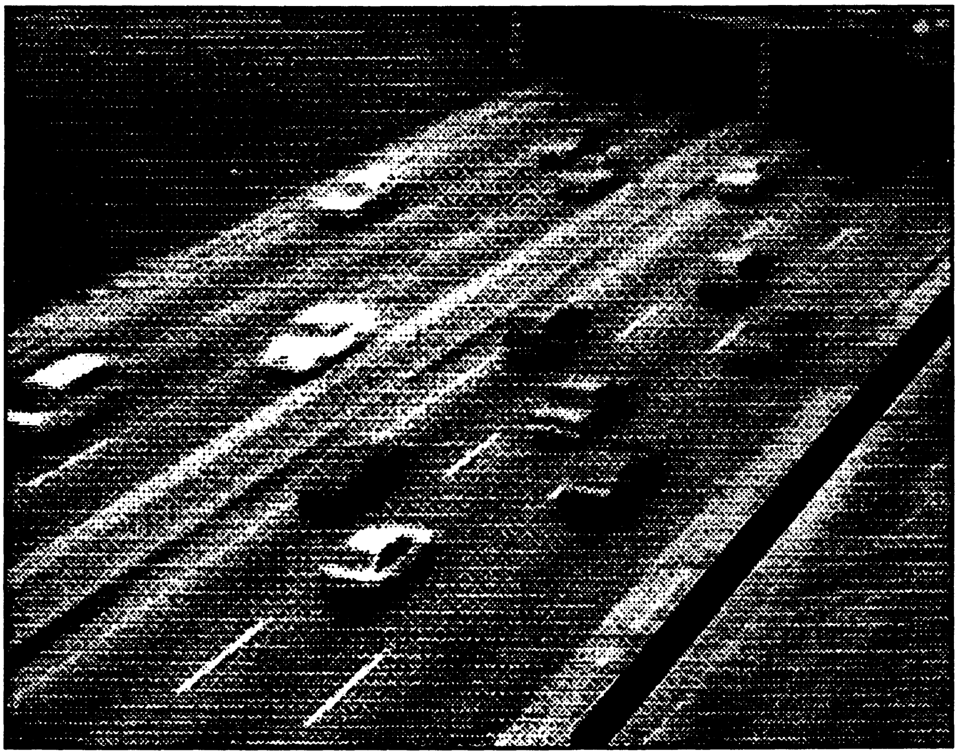


Figure 7. Sample still video screen.
Note: Traffic speed is color coded.

The height, angle, and field of view of the camera varied among the video screens. Subsequently, the side of the road of interest and its direction of traffic flow (toward or away from the camera) varied from screen to screen. For example, only one side of the highway is visible in some screens, whereas both sides are visible in others. In addition, the picture quality (color and clarity) also varied. These were the only images available, however, so the higher quality frames were reserved for the test sequence.

Moving video screens

The moving (dynamic) video screens showed recorded footage of actual traffic along I-94, obtained from SCANDI stationary video cameras along the expressway. These were selected from the same footage collected for the still video screens. As a result, the camera angle, field of view, picture quality, and direction of traffic flow varied from screen to screen.

For each route, one scene along the affected area was displayed. In other words, the camera did not pan across the entire affected area. Contrary to the still video screens, the moving video screens did not contain colored line cues to indicate the problematic side of the road. Instead, the subject determined this by looking for the side closest to the camera, covering the largest visual angle. A sample video screen is included in Figure 8.

Figure 8. Sample moving video screen showing affected area of a route.

Test Activities and Their Sequence

Each subject participated in one test session which lasted approximately two hours. Testing took place over one week of fair weather at 10 a.m., 1 p.m., 4 p.m., and 6 p.m. Traffic was light to moderate. Participants met the experimenter at the University of Michigan Transportation Research Institute (UMTRI). (The complete instructions appear in the appendix.) Upon arrival, participants were taken to a conference room. The purpose of the experiment and an overview of the procedure were explained. The participants then read and signed the consent form.

Subsequently, the biographical form was completed. (Copies of the consent and biographical forms are also in the appendix.) The form asked for each driver's name, age, occupation, education level, and their driving experience (annual mileage, the type of car driven, familiarity with maps and the metro Detroit area, and use of HUDs).

Next, the participant's corrected visual acuity was measured using a Titmus Vision Tester. Any corrective lenses that were worn during driving were worn for the vision test. It was noted on the biographical form whether or not the participant wore glasses or contact lenses.

Afterwards, the participant was taken to the instrumented car. While the participant adjusted the driver's seat to get comfortable, the experimenter turned on the external power source and started the practice trial. The practice session contained two examples (trials) of each of the four traffic information system interfaces (text, graphic, still video, moving video). The sequence of interface presentation (test blocks) was the same for all participants (graphic, still video, text, moving video), but the interface that was shown first was counterbalanced across subjects.

When the system was ready, the basic activities of the study, the test route to be driven, and the use of the system were explained in detail. The premise of the experiment was that the driver was traveling east on I-94 to the Renaissance Center in downtown Detroit. In reality, they would be driving west on M-14 from Exit 20 (Sheldon Road) to the US-23 exit. Both are 4-lane expressways. The test route is displayed in Figure 9. While driving, an overview of traffic problems and their severity along two routes was displayed on the monitor using a color-coded skeleton map. Two possible routes (A and B) to the destination were available, which, under normal traffic conditions, were considered equal in distance, travel time, and road condition.

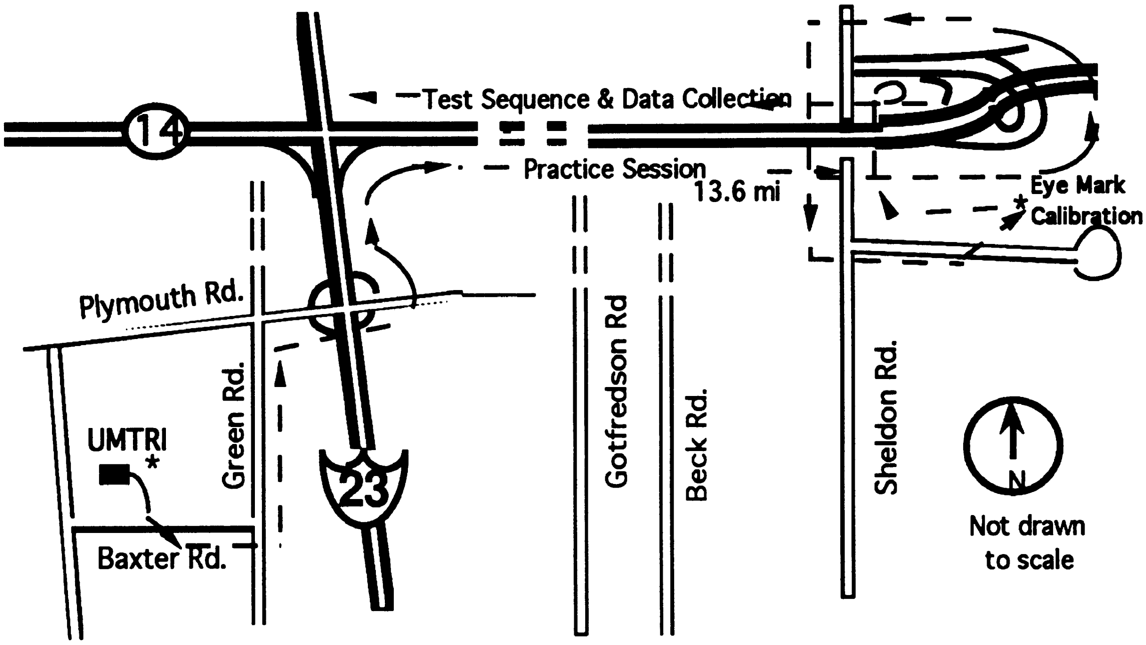


Figure 9. Test Route.

More detailed information concerning both routes was obtained by pressing the corresponding button for route A (the A button) and then route B (the B button). It was at this detailed level that the four interface styles were tested. After viewing both detailed information screens and as soon as a choice was made, the participant pressed a button corresponding to the preferred route. Figure 10 shows the timing.

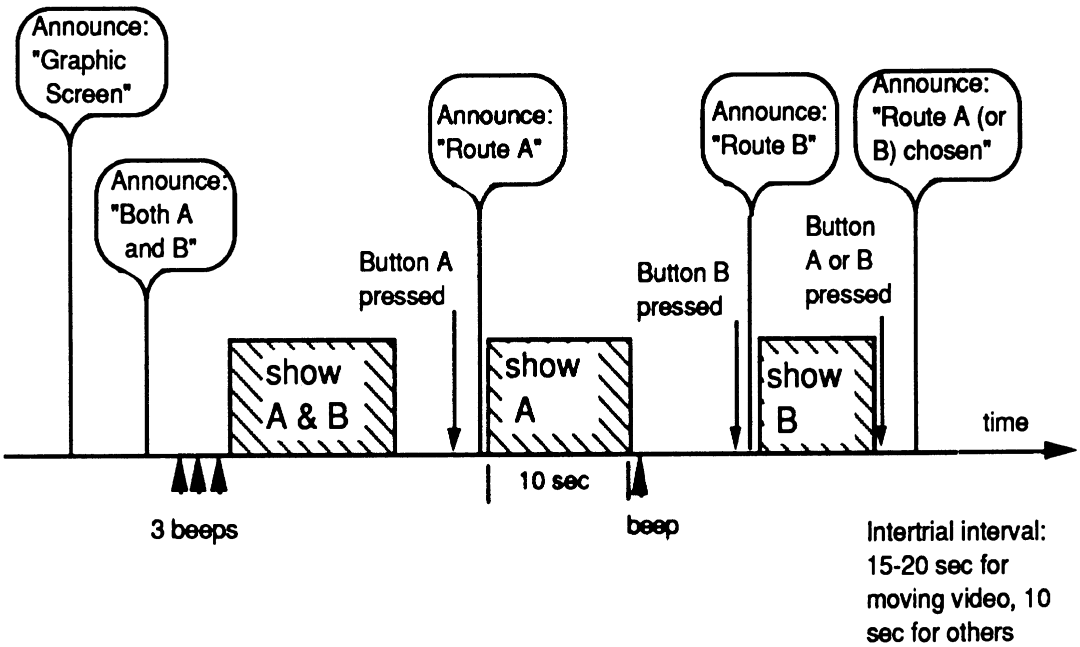


Figure 10. Screen presentation, announcement, and subject response timing.

Traffic information was shown on an in-car LCD display mounted on the instrument panel. Preceding the first trial in each block, an announcement stated the format in which the information would be displayed: "graphic screens," "text screens," "moving video screens," or "still video screens." The speaker was located on the arm rest between the two front bucket seats. At this point, the screen was gray and blank. Next, an announcement stated the route content of the introductory screen ("both A and B") followed by three beeps, and presentation of that screen.

Any time beyond that point, after viewing the introductory screen, the driver was able to view more detailed information on problems along the two routes. The problem severity was always similar along each of the routes within that trial, such that route choice was indiscernible with the information provided by the introductory screen. The system waited indefinitely at this point for the subject to press button A (to look at route A more closely).

When button A was pressed, an announcement declared the route content of that screen, saying "route A." This was followed by the presentation of the route A detailed information screen in the format previously announced. This screen was displayed for 10 seconds before vanishing (signaled with a beep). Pressing a button during this time only resulted in a beep and no screen change. After the route A screen disappeared, the driver viewed route B in more detail by pressing the B button.

The route B screen was introduced with the announcement "route B." This screen was displayed until either the driver pressed a button corresponding to the route decision, or after 10 seconds elapsed without a response. The subjects were instructed to respond (by pressing the appropriate button) as soon as a route choice was made. When a button was pressed (whether the route B screen was still displayed or not), that response was announced, as "route A (or B) chosen." Following an interval, the next trial began. Intertrial intervals were 10 seconds for all systems, except for moving video which ranged from 15 to 20 seconds. The latter time was restricted by the PC-VCR capabilities.

After describing the general use of the system, and walking through one trial interface, the eye camera was fitted on the participant. The rest of the practice session and system explanations were conducted with the eye camera on, but not calibrated. After the practice session, the eye camera was removed and any questions were answered.

This first practice session served multiple purposes. Primarily, it served to familiarize the driver with the system, its use, and the four interfaces. Additionally, it provided an opportunity for the subject to wear the eye camera while using the system, to become accustomed to the camera's weight, and identify any discomfort. Also, any objections to the use of the eye camera could be voiced at that point, before getting on the road, to avoid participants withdrawing from the experiment while away from UMTRI.

With the practice done, the participant adjusted steering wheel and mirrors, and began driving. The driver became familiar with the instrument panel (climate control, etc.) while the experimenter prepared the systems. The driver was then directed to

US-23 North. (For a more detailed route description, see the map in the Test Plan.) Participants were asked to drive within the 65 mph speed limit and in the right hand lane when possible. Upon reaching US-23, the experimenter began recording from the forward scene and driver cameras. Baseline driving data (steering wheel angle, etc.) was also collected then. The experimenter provided assistance to the driver by monitoring traffic conditions and other vehicles on the road.

The second practice session began at M-14 East. The same practice sequence (as seen in the walk-through) was used, with the same two screens per interface and the same presentation order. Output from the rear and forward view cameras for this practice session was recorded. Approximately 10 minutes were needed to complete this practice, so it was always finished before reaching the turnaround exit (Exit 20, Sheldon Road). The area beyond Exit 20 was avoided because the traffic was noticeably greater.

At that exit, the driver was directed to a parking lot, about 1/4 mile from the exit ramp. This empty parking lot was easy to get to from US-23, which was important given the reduced peripheral vision experienced by drivers when wearing the eye camera. While in the parking lot, the eye camera was put on the participant and calibrated by the experimenter. (A description of the calibration procedure appears in the appendix.) The road scene and driver camera cables were disconnected from the VCR, and the eye camera cables were connected.

Guided by the experimenter, the participant drove back on M-14 heading west. At a safe point, the actual test sequence and data collection were begun. This sequence contained twice as many trials, four per interface, as did the practice sessions. Because subjects took variable amounts of time to complete the experiment, the test was finished at different points along M-14, all within approximately 1 mile of the US-23 interchange. The driver remained on M-14, however, until all the trials were completed. Data collection ended after all the test displays were viewed. All subjects took one of two exits off of M-14: to US-23, or to Main Street, downtown Ann Arbor. Participants were given the choice of either stopping in a parking lot or waiting until reaching UMTRI to have the eye camera removed.

Back at UMTRI, the participant remained in the driver's seat, without the eye camera. The four moving video trials from the test sequence were replayed for the participant. The participant's task was to estimate the average speed (mph) of the traffic lanes, for all eight detailed route screens. Subjects stated one speed if all three lanes were moving at approximately the same rate, but provided separate speeds if traffic was moving at different rates. Lastly, participants ranked the four interfaces from best to worst (from 1 to 4). They were then asked if they would be willing to buy any of the four systems, and subsequently how much they would be willing to pay. These responses were recorded by the experimenter. Finally, participants signed the payment form, were paid and thanked for their time.

Results

Which Form of Traffic Information Is Least Distracting?

In this experiment, distraction of the traffic information display was measured by how often and how long drivers looked at it. There were significant problems with the eye-fixation recording system, especially for drivers who wore glasses or contacts. As a consequence, useful eye-fixation data was only obtained from five of the twelve drivers.

Table 2 shows the mean duration and number of fixations while screens A and B were presented to those drivers. Screen A was shown for a fixed amount of time (10 seconds) while screen B was cleared when the subject selected a route. Typically it took less than 10 seconds to make the route A or route B decision. Therefore, the number of glances to screen B tended to be less. Several of the glances to screen A are associated with the subject forgetting what was shown and looking back to refresh his or her memory, an experimental artifact. (For a variety of equipment-related reasons, it was not possible to have the duration of both screens A and B determined by the subject.) Other fixations associated with screen A involve the driver checking to see if screen A has cleared. This occurred even though a beep was presented when the screen cleared. This supposition is confirmed by the glance durations, which were too short to constitute anything but checking.

Table 2 Number of eye fixations and mean length (msec).

Format	Screen A				Screen B			
	world		monitor		world		monitor	
	length	num	length	num	length	num	length	num
Text	802	9.4	426	6.2	733	3.1	468	2.9
Graphic	941	8.0	448	6.4	811	2.7	493	3.0
Still	889	7.0	555	7.1	774	3.9	543	4.9
Motion	995	7.4	507	7.5	694	4.3	466	4.8

In spite of this confounding, it is interesting to note that subjects made fewer glances to the monitor for text and graphic displays (1/2 to 1 glance less on average). This trend is further supported by the duration times with text having the shortest glance durations (426 msec) followed by graphic (448), motion video (507) and still video (555). This range represents a 30% difference.

The results also indicate that participants made their route decisions (the screen B times) with fewer eye glances when using the text and graphic displays (about 3 glances) than with the still or moving video displays (about 4.9 glances). With the exception of the still video, there was little difference between the glance duration times of each display. The total eyes-on-the-display time (the product of glance duration and number of glances) reflect even larger differences, as shown in Figure 11. In the figure, this corresponds to the area of the rectangle formed by the data point and the origin, which depends primarily on the number of fixations.

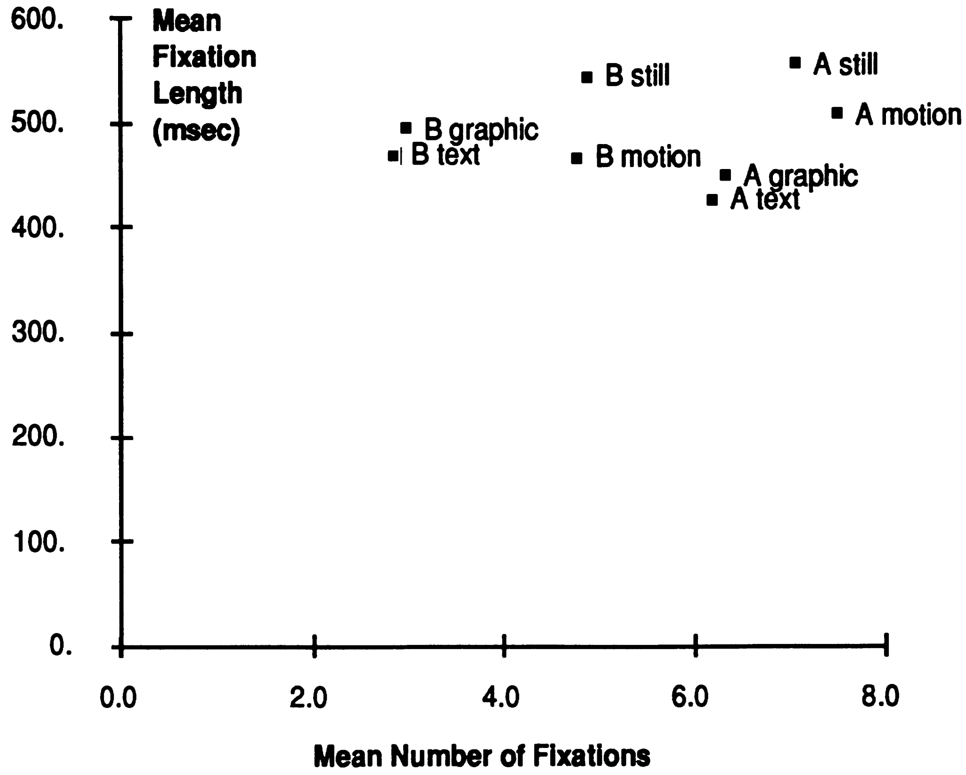


Figure 11. Fixation durations and numbers for screens A and B.

Table 3 shows the mean fixation durations for individual drivers. Given the limited number of fixations per driver, the ordering of systems for each participant was not always the same as the group means. (That is, text and graphic displays did not always have briefer glance durations and lower frequencies than moving and still video displays.)

Which Interface Requires the Least Amount of Time to Use?

Shown in Table 4 are the mean times as well as the minima and maxima for the delay between seeing A and B and requesting A, seeing A and requesting B, and selecting a route after seeing B (the response time). Subject mean times ranged from 516 msec to 11041 msec for requesting A. For requesting B, there was less variability with means ranging from 1861 to 4233 msec.

Table 3. Eye fixation means and standard deviations by subject and system.

Subject	System	Screen A mean (msec)	Screen A sd (msec)	Screen B mean (msec)	Screen B sd (msec)
5	Graphic	818	914	698	417
	Motion video	759	618	520	286
	Static video	892	746	827	610
	Text	762	832	785	650
7	Graphic	688	587	560	479
	Motion video	495	258	508	407
	Static video	633	447	796	843
	Text	630	528	509	306
10	Graphic	497	531	376	213
	Motion video	722	1079	507	292
	Static video	553	345	441	203
	Text	694	919	453	272
11	Graphic	894	844	1060	987
	Motion video	812	1010	641	480
	Static video	847	618	638	417
	Text	368	244	475	362
14	Graphic	675	518	557	366
	Motion video	816	859	875	1069
	Static video	662	483	509	353
	Text	633	545	747	823

Table 4. Button Press Times

subject #	request screen A mean (min,max) ms	request screen B mean (min,max) ms	select route mean (min,max) ms
5	516 (233,1683)	2543 (400,5583)	3620 (2333,5067)
6	5052 (2900,12967)	3161 (1567,9383)	3562 (2300,5000)
7	1213 (383,2400)	2123 (1083,7733)	3541 (1017,5533)
8	2722 (1217,7250)	1861 (450,4183)	7567 (3950,11967)
9	4221 (1583,21500)	2905 (1050,12900)	6052 (3667,10600)
10	2420 (1517,3100)	2083 (967,3533)	3492 (1800,6983)
11	11041 (1333,44483)	3735 (967,15067)	4875 (1333,15217)
12	2109 (983,6883)	4233 (1450,17117)	5038 (2367,23583)
13	2220 (367,5967)	2572 (383,12750)	5028 (1833,11633)
14	6689 (2067,26883)	2642 (567,6167)	6915 (333,13100)
15	3946 (2350,7150)	3035 (1833,6483)	5004 (2567,7683)
16	5051 (1283,26333)	3050 (1433,9183)	5792 (1233,12367)

The most important of these dependent measures is the response time to select a route. A two-way ANOVA (Subjects x System) of those times indicated significant effects due to Subjects ($F(11,144)=5.82$, $p<.001$) and Display Formats ($F(3,144)=17.05$, $p<.001$), as well as their interaction ($F(3.144)=2.45$, $p<.001$). When Subjects was replaced with Sex in the ANOVA, neither the main effect of Sex nor the interaction with it were significant. Subject response times for route selection ranged from 3541 to 6915 msec. Response times for the various formats were 3738 msec for text, 4036 for graphic, 6025 for still video, and 6363 for moving video as shown in Table 5. For correct responses only, the times were 3668, 3896, 4103, and 7234 for text, graphic, still, and moving video formats respectively. In a detailed ANOVA of only correct responses (examining Sex, Order, Subjects, and Format as main effects), Format was again significant ($p<.01$).

Table 5. Response Times for Each Display Type (msec).

System	mean	min	max
Graphic	4036	1567	9700
Motion	6363	333	15217
Still	6025	1333	23583
Text	3738	1017	11050

Which Interface Minimizes Decision Errors?

The success rates (percent correct) were 95.8% for the text and graphic screens, 56.2% for the still video, and 62.5% for the moving video. (All participants responded incorrectly to one of the still video screens. When that data point is removed, the success rate goes up to 72.2%) An ANOVA of the uncorrected data with Sex, Order, Subject nested in group, and Display Format as the main effects showed that only the effect of Display Format was significant ($F(3, 9)=30.06$, $p<.001$). An ANOVA of the corrected data leads to the same conclusion though the F value drops to 14.54, which remains very highly significant. Thus, from the perspective of selecting an optimum route, drivers were significantly more likely to be correct using text or graphic displays than using still or moving video formats.

Subjects were asked to estimate the average speed of traffic (in mph) of all three lanes on the problematic side of the road for the moving video system. When individual lane estimates were given, they were later averaged into one speed estimate per route. In Table 6, for each trial, the mean of all subjects' estimates of traffic speed on the problematic side of the road is compared with the actual mean. As shown in Figure 12, motorists tended to be more accurate in estimating the speed of traffic flow for the faster moving traffic. Stated another way, drivers had difficulty perceiving slow moving traffic.

Table 6. Actual and estimated mean speed of traffic lanes for each moving video screen (mph).

	slower - - - - - - - - - - - - - - > faster							
Actual mean speed (mph) of traffic in all 3 lanes	12.0	15.0	20.0	23.0	28.0	38.0	30.0	40.0
Mean of all subjects' speed estimates for all 3 lanes	32.4	36.2	34.2	37.2	39.2	40.8	45.3	47.2
Difference (mph)	20.4	21.2	14.2	14.2	11.2	2.8	15.3	7.2
Difference (%)	170.	141.3	71.0	61.7	40.0	7.4	51.0	18,0

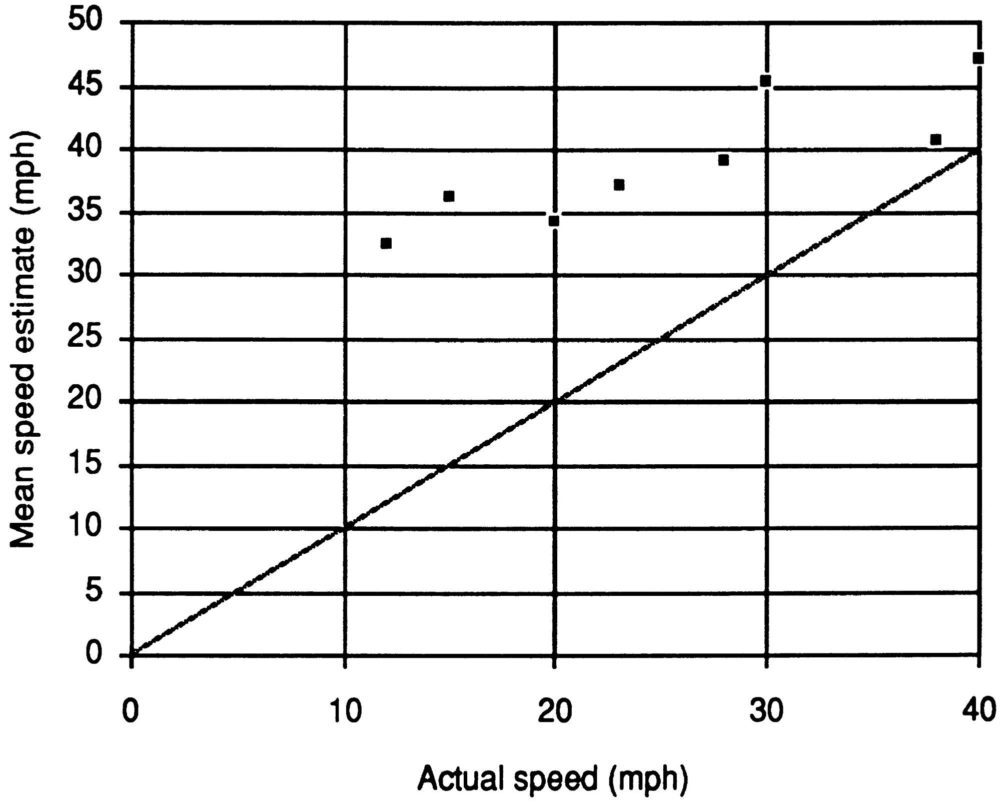


Figure 12. Estimated and actual speeds.

Which Interface Is Preferred by Drivers?

Subjects were asked to rank the four systems from best (1) to worst (4), in order of preference. (For more detailed listing of subject preferences, refer to the appendix.) A Kruskal-Wallis one-way analysis of variance of the ranks, grouped by system, indicated that text screens were preferred, KW(3) = 27.9 (p=0.00). The text screens received the best mean preference ranking, and the most top rankings, as shown in Table 7.

Table 7. Mean rank of each system (n=12 subjects).

System	Number of rankings				Mean Rank
	Best ------>			Worst	
	1	2	3	4	
Text	9	3	0	0	1.25
Graphic	2	7	1	2	2.25
Moving video	1	1	8	2	2.92
Still video	0	1	3	8	3.58

How Much Are Drivers Willing to Pay for These Systems?

Subjects were asked if they would be willing to buy any of the four systems. For traffic information systems that they might buy, subjects were asked how much they would be willing to pay if the systems were considered comparable to a good car stereo. These responses are summarized in Table 8.

Table 8. Willingness to Pay Data.

System	Number willing to buy (n=12)	Mean price willing to pay	Range
Text	9	\$378	\$100 - \$1000
Graphic	6	\$358	\$200 - \$550
Moving video	4	\$650	\$200 - \$1000
Still video	1	\$200	\$200

While more participants would be willing to buy the text system, a higher average price was stated by people willing to buy the moving video system. The text system was the most popular, with 9 of 12 (75%) of the subjects indicating that they would be willing to buy it. The average price stated by those participants was \$378. Also, half of the subjects said that they would be willing to buy the graphic system, stating an average of \$358. Less than half of the people would consider buying either of the video systems. The prices given by the four people who would buy the moving video system, however, averaged \$650, the highest average price. Perhaps this is due to the perceived complexity of such a system.

Conclusions and Recommendations

Which Interface Format Is Best?

This research examined five questions:

- Which form of traffic information is least distracting?
- Which interface design requires the least amount of time to use?
- Which interface minimizes decision errors?
- Which interface is preferred by drivers?
- How much are drivers willing to pay for these systems?

Which form of traffic information is least distracting?

As indicated by the eye fixation data, the text display was the least distracting. It resulted in the briefest fixations, followed by the graphic, and then both video-based displays. There was a 30% difference in glance durations across the range. The rank orderings of the number of glances required for each format were similar and of the same magnitude.

For the text display, the driver only had to search for the delay time and read it. In the case of the graphic display, the driver's task was to search for the colored route segment, judge its length, and then find and read the speed for that link. Since many of the segments were curved (as is the case for real roads), this did not occur quickly.

For both video formats, drivers had to scan the displays carefully, first to find which lanes they were to observe (indicated by a yellow or red band on the side of the road), and subsequently to look in several places to make judgments about gap sizes. Obviously, this required several eye fixations. In the case of the moving video, drivers had to view video segments for some time to judge how quickly traffic was moving.

Which interface design requires the least amount of time to use?

The pattern of results for the response times follow the same pattern as the eye-fixation data. Response times were briefest for the text format, with times for the graphic format being somewhat greater. Times for both video formats were significantly greater. It is believed that the primary factor affecting decision time was how long it took the driver to perceive the speed shown. The decision itself should be made quite quickly. In this experiment, perception of the second screen and responding to it were the same timed interval.

For text displays, selecting the best route involved comparing the delay time shown on the second screen with the value recalled from the first and then selecting the smallest value--an easy task. For the graphic displays, the comparison was of the remembered length of a curved line and speed with the same information for a second line shown--a more difficult task. For the static video, the drivers needed to estimate an average gap size and compare it with a remembered gap size, which was even more difficult. Finally, in the case of moving video, the comparison was of a moving flow rate (obtaining by looking at a sequence of frames) with a remembered rate. This was most time consuming.

Which interface minimizes decision errors?

A good display is not only ease to use, but provides useful information as well. Success rates for decisions were well over 90% for the text and graphic screens, while considerably lower for moving and still video. In the text displays, the delay time for each route was shown directly, simplifying the decision. This information was not available directly from other interface formats.

One of the still video screens showed traffic that was moving quickly but was closely spaced. When comparing this screen with one with less density (but slower travel speeds), all subjects mistakenly chose the less dense route. This highlights one of the problems of using still video. There is not a one-to-one correspondence between either the number of vehicles shown in a scene (or their spacing) with the speed at which they are moving, making judgments less accurate.

Which interface is preferred by drivers?

Consistent with the driver performance data is the preference data. Differences were clear and statistically significant. The rank order (from best to worst) was the same as for eye fixations and response times--text, graphic, and both video formats, though the moving video was preferred over the still video.

How much are drivers willing to pay for these systems?

About three quarters of those responding would buy a text based system (for about $375) while only half would buy a graphic-based system (for almost the same price). Only a few of the participants would buy the other systems.

As an aggregate, these data suggest that there may be a market for traffic information displays, and, they indicate a strong preference and performance advantage to presenting traffic information as text. For simple two-choice decisions such as examined in this experiment, text displays are recommended to present traffic information to drivers in moving vehicles. Decisions using that format required fewer eye fixations (were less distracting), took less time, and were more likely to be correct. Drivers preferred that format, and about 3/4 of those responding would be willing to buy such a system.

How Can the Presentation of Video Traffic Information Be Improved?

While in-vehicle use of video traffic information is not supported by the results of this experiment, widespread use in traffic control centers is likely to continue. Observations of personnel in the SCANDI center and participants in this experiment, as well as efforts associated with creating experimental materials, have provided insights into how video traffic information should be presented. One reason why drivers may have taken a long time to respond to the video images was due to the suboptimal quality. (They were fuzzy.) However, these were the best images the authors could obtain at the time and represent a real implementation constraint. If they had been broadcast, further degradation was likely. It was also evident that the location of the cameras relative to the highway (angle of view, field of view, whether the desired lane was near or far, if the traffic was oncoming or going away, etc.) all qualitatively influence the time to make a decision. At SCANDI, large labels were placed near the monitors to identify the roads being shown. To the best of the authors' knowledge, there are no studies in the literature that address these presentation issues. Given the expanding use of traffic control centers and increased concern with operator performance, these questions should be addressed. In spite of these concerns, the authors still believe that static and dynamic video do not warrant further consideration for in-car traffic information displays.

How Can the Data Collection Process Be Improved?

One of the major problems in this experiment was obtaining reliable in-vehicle data. This project was the first in which a vehicle was used and difficulties arose in obtaining steering and speed data free from electrical interference. The software has been revised and these problems have been eliminated. The lesson is that one cannot expect to obtain complete data for the first experiment involving a complex device such as an instrumented car.

There were particular problems in obtaining reliable eye-fixation data. The data collection software has been modified to present the coordinates in real time, and experimenters have been alerted to watch for such errors during data collection. This should improve the quality of data in future experiments and simplify analysis. Some additional effort is needed to identify appropriate angular changes associated with the beginning of eye fixations.

In spite of the difficulties encountered, the experiment provides conclusive evidence that static and dynamic video is not the preferred means for showing traffic congestion to drivers. Properly designed text and graphic displays take less time to read, are more likely to lead to correct decisions, and are preferred by drivers.

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Appendix A - Experimental Procedure

This appendix describes the experimental procedure used for this study. Instructions to the experimenter are shown in *italics* and suggested dialogue is shown in **UPPERCASE BOLD**. Eye camera calibration instructions follow in the subsequent appendix.

IN-CAR TRAFFIC INFORMATION STUDY INSTRUCTIONS

Before subject arrives:

Check schedule to determine subject name, number and designated primary system order (according to counterbalanced ordering.)

Test Vehicle Activities (if first subject of the day)

Get the keys and be sure car is not blocked in. Make sure the car has gas if needed after last testing session. Open trunk and plug in blue extension cord to wall outlet. Turn on converter to ***EXTERNAL*** *power. Turn on PC-VCR and change channel to "L." Start up Macintosh, and select* ***"Diversion"*** *stack. Click on* ***"Change Subject"*** *and type in subject's name and number in field. Click on the system designated to be first. Move the mouse cursor to* ***Practice.***

General Activities in Conference Room (#301 UMTRI)

Set up Titmus vision tester in conference room. Have ready a consent form, biographical form, ranking preference, speed estimate & price willing to pay forms, payment forms (University employee or non-U employee), and $25.00 cash (if subject is not a University employee). Also have a VCR tape labeled with subject name and number. Fill in as much information on the bio form as possible.

When Subject Arrives

HI, ARE YOU _________?(use subject's name) **I'M** __________(experimenter's name). **THANKS FOR COMING, LET'S GO DOWN TO THE CONFERENCE ROOM SO WE CAN BEGIN.**

Take subject down to conference room and be seated.

AS I MENTIONED EARLIER, THIS STUDY WILL TAKE ABOUT 2 HOURS TO COMPLETE, AND YOU'LL BE PAID $25.00. IT INVOLVES A SHORT DRIVE IN AN INSTRUMENTED CAR.

THE PURPOSE OF THIS EXPERIMENT IS TO DETERMINE THE BEST WAY TO PRESENT DRIVERS WITH TRAFFIC INFORMATION IN CARS OF THE FUTURE. SINCE PEOPLE WILL BE DRIVING WHILE OBTAINING TRAFFIC INFORMATION, THE SYSTEM MUST BE EASY TO USE AND NOT DISTRACT DRIVERS FROM LOOKING AT THE ROAD. SINCE PEOPLE LIKE YOU WILL BE DRIVING THOSE VEHICLES, YOUR OPINION IS IMPORTANT.

BEFORE WE START, THERE IS SOME PAPERWORK TO COMPLETE. FIRST YOU NEED TO READ AND SIGN THIS OFFICIAL CONSENT FORM, WHICH BASICALLY REPEATS IN WRITING WHAT I JUST SAID. I ALSO WANT TO REITERATE THAT THE AIRBAG HAS BEEN DISABLED IN THE RESEARCH CAR TO AVOID INTERFERENCE WITH OTHER EQUIPMENT.

Have participant read and sign the consent form.

ALSO, WE NEED TO KNOW A LITTLE MORE ABOUT YOU.

Go through bio form with subject and fill in the appropriate answers.

NOW WE CAN CHECK YOUR VISION.

Turn on both eye switches on the vision tester, slide 1, "far". Adjust the height of the vision tester for the subject. Make sure subject wears any vision corrector they would if driving, and note it on bio form.

CAN YOU SEE THAT IN THE FIRST DIAMOND THE TOP CIRCLE IS COMPLETE BUT THE OTHER 3 (ON THE RIGHT, LEFT, AND BOTTOM) ARE INCOMPLETE? CAN YOU TELL ME WHICH CIRCLE IS COMPLETE IN THE SECOND DIAMOND? THE THIRD?...

Prompt the subject until s/he has missed two in a row. Record the last number answered correctly and the corresponding visual acuity on the bottom of the bio form.

WE CAN NOW GO DOWN TO THE RESEARCH CAR.

Take subject downstairs to the High Bay (UMTRI garage). Let subject sit in the driver's seat and get comfortable. Experimenter sits in the front (passenger side).

Explain systems to subject:

LIKE I SAID BEFORE, THE PURPOSE OF THIS STUDY IS TO DETERMINE THE BEST WAY TO PRESENT TRAFFIC INFORMATION TO DRIVERS. TRAFFIC INFORMATION WILL BE DISPLAYED TO YOU IN DIFFERENT WAYS ON THIS MONITOR *(point)* **WHILE YOU ARE DRIVING ALONG M-14 (EAST).**

BEFORE WE GO OUT ON THE ROAD, I'M GOING TO SHOW YOU EACH OF THE 4 TYPES OF TRAFFIC DISPLAYS YOU'LL SEE. I'LL GIVE YOU PRACTICE USING THIS SYSTEM, WHILE WEARING THE EYE CAMERA. AFTER WE RUN THROUGH THE PRACTICE WE'LL GO OUT TO US-23 NORTH, AND TAKE THAT TO M-14 EAST. ON M-14 YOU WILL GO THROUGH THE PRACTICE AGAIN (WITHOUT THE EYE CAMERA). THEN WE'LL EXIT AT SHELDON RD., EXIT 20, WHERE I'LL PUT THE EYE CAMERA ON YOU. ON THE WAY BACK TO UMTRI WE'LL COLLECT DATA WITH THE EYE CAMERA ON. OK? THE EYE CAMERA MEASURES YOUR PUPIL DIAMETER AND TELLS US HOW INTERESTING YOU FIND THE DISPLAYS.

LET ME EXPLAIN GENERALLY HOW THIS WORKS:
IN THIS STUDY, YOU WILL PRETEND TO BE DRIVING EAST ON I-94 TO THE RENAISSANCE CENTER IN METRO DETROIT (ACTUALLY YOU'LL BE ON M-14). THERE ARE TWO ROUTES YOU COULD TAKE TO GET TO THAT DESTINATION (CALL THEM ROUTE A AND B). ON THE SCREEN, YOU WILL RECEIVE TRAFFIC INFORMATION ABOUT EACH ROUTE. FIRST, YOU WILL BE SHOWN GLOBAL TRAFFIC INFORMATION FOR BOTH ROUTES. THEN, BY PRESSING THESE BUTTONS *(point)*, **YOU WILL BE ABLE TO TAKE A CLOSER LOOK AT EACH OF THE ROUTES (FIRST A, THEN B) TO GET MORE DETAILED TRAFFIC INFORMATION. YOU WILL BE PRESENTED WITH THAT DETAILED INFORMATION IN 4 DIFFERENT FORMATS. (THE GLOBAL SCREEN WILL ALWAYS BE IN THE SAME FORMAT.) AS SOON AS YOU HAVE SEEN BOTH ROUTES, YOU WILL DECIDE WHICH ROUTE YOU WOULD TAKE, AND PRESS THAT BUTTON. (YOU WON'T ACTUALLY BE MAKING THESE TURNS.)**

Click on **Practice**.

THIS IS THE GLOBAL SCREEN THAT SHOWS YOU BOTH ROUTES. THIS SCREEN IS IN THE SAME FORMAT FOR ALL 4 SYSTEMS. (I'LL EXPLAIN THEM IN A MINUTE.) HERE YOU CAN SEE BOTH ROUTES, A AND B *(point)*. **THE GRAY LINE INDICATES THE ROUTE YOU WOULD TRAVEL. (SINCE YOU DRIVE ON THE RIGHT SIDE OF THE ROAD, ONLY THAT SIDE IS IMPORTANT TO YOU.) THIS ARROW IS YOUR VEHICLE** *(point)* **AND THE STAR** *(point)* **IS YOUR DESTINATION (THE REN CEN). DURING NORMAL TRAFFIC CONDITIONS BOTH ROUTES TAKE THE SAME AMOUNT OF TIME TO DRIVE AND ARE THE SAME DISTANCE. THE CONDITION OF BOTH ROADS IS EXACTLY THE SAME, ALSO.**

YOU WILL BE GIVEN TRAFFIC INFORMATION ON THE MONITOR WHICH TELLS YOU ABOUT PROBLEMS ALONG THE ROUTES, AND THE SEVERITY OF THOSE PROBLEMS. IF A TRAFFIC PROBLEM OCCURS, THE AFFECTED AREA OF THAT ROAD IS SHOWN IN RED OR YELLOW. YELLOW AREAS MEAN THAT TRAFFIC IS FLOWING SLOWLY (BETWEEN 30 - 50 MPH), AND RED AREAS INDICATE VERY SLOW, CRAWLING TRAFFIC (UNDER 30 MPH). OTHERWISE, GREEN ROADS MEAN THAT TRAFFIC IS FLOWING NORMALLY. THE NORMAL SPEED LIMIT FOR CARS IS 65 MPH.

ANYTIME AFTER A SCREEN LIKE THIS ONE IS PRESENTED, YOU CAN VIEW EACH ROUTE IN MORE DETAIL BY PRESSING THE BUTTONS CORRESPONDING TO THE ROUTES. IN THIS STUDY, <u>PLEASE VIEW ROUTE A, AND THEN ROUTE B</u>, AND DECIDE WHICH ROUTE YOU WOULD TAKE BASED ON THE TRAFFIC INFORMATION PROVIDED. YOU <u>MUST VIEW ROUTE A FIRST</u> (IF YOU TRY TO LOOK AT ROUTE B BY PRESSING THE B BUTTON, IT WILL BEEP AND NOT DO ANYTHING).

WHEN YOU VIEW ROUTE A BY PRESSING THE A BUTTON, YOU WILL HEAR AN ANNOUNCEMENT TELLING YOU THAT IT IS "ROUTE A." THAT TRAFFIC INFORMATION SCREEN WILL STAY ON THE DISPLAY FOR 10 SECONDS. AFTER THAT POINT, YOU WILL HEAR A BEEP, AND THE ROUTE A SCREEN WILL VANISH.
*Have subject press button **A**. Wait for A to disappear.*

WHEN THE ROUTE A DISPLAY DISAPPEARS (AND YOU HEAR THE BEEP) YOU CAN PRESS THE B BUTTON TO VIEW ROUTE B IN MORE DETAIL. *Have subject press button B.*

ANOTHER ANNOUNCEMENT WILL TELL YOU THAT YOU ARE LOOKING AT "ROUTE B." <u>AS SOON AS THE ROUTE B SCREEN IS DISPLAYED AND YOU DECIDE WHAT ROUTE YOU WOULD TAKE, PRESS THE BUTTON FOR THAT ROUTE (A OR B), EVEN IF THE ROUTE B SCREEN IS STILL DISPLAYED.</u> *Have subject make selection and press that button.*

THE ROUTE YOU CHOOSE WILL BE ANNOUNCED, AS "ROUTE A (OR B) CHOSEN." REMEMBER, IT IS IMPORTANT THAT YOU PRESS THE BUTTON AS SOON AS YOU MAKE YOUR ROUTE DECISION. ALSO, YOU CAN ONLY VIEW EACH ROUTE ONCE, AND CANNOT GO BACK TO THE GLOBAL DISPLAY. YOU SHOULD TREAT EACH ONE OF THESE TRIALS INDEPENDENTLY, IN OTHER WORDS, THE INTRODUCTORY SCREENS ARE NOT "UPDATES" ON THE CONDITION OF THE ROUTES. ANY QUESTIONS? *Review if necessary.*

THE INTERFACE YOU JUST SAW WAS THE ________ (graphic, still video, text, or moving video) DISPLAY. LIKE I SAID BEFORE THERE ARE 4 DIFFERENT FORMATS FOR THE DETAILED TRAFFIC INFORMATION. IN THE PRACTICE, AND IN THE REAL STUDY, YOU WILL HEAR AN ANNOUNCEMENT TELLING YOU WHICH OF THE FORMATS THE DETAILED INFORMATION WILL BE IN: GRAPHIC SCREENS, TEXT DISPLAYS, MOVING VIDEO SCREENS, AND STILL VIDEO SCREENS. IN THE PRACTICES YOU WILL SEE 2 TRIALS OF EACH DISPLAY, AND DURING THE TEST SEQUENCE YOU WILL SEE 4 TRIALS OF EACH DISPLAY, IN A ROW.

BEFORE YOU GO THROUGH THE REST OF THIS PRACTICE SESSION, LET ME PUT THE EYE CAMERA ON YOU, SO YOU CAN GET USED TO USING THE SYSTEM WITH IT ON.

Put the eye camera on the subject, but do not calibrate.
IS THAT COMFORTABLE? AS YOU GO ALONG, I'LL EXPLAIN EACH SYSTEM WHEN YOU GET TO IT. WHY DON'T YOU FINISH THE ________ DISPLAYS?

When you get to the Still Video Screen:

THESE PICTURES (AND THE MOVING VIDEO ONES) WERE TAKEN FROM TV CAMERAS ALONG THE HIGHWAY. THE IMAGE QUALITY WILL BE BETTER IN THE REAL SYSTEM. THE COLOR STRIP ALONG THE SHOULDER INDICATES THE SIDE OF THE ROAD THAT YOU ARE CONCERNED WITH, AND REMINDS YOU OF THE SPEED OF THAT TRAFFIC. SOMETIMES THE TRAFFIC LANES OF INTEREST WILL BE MOVING TOWARDS YOU AND OTHERS TIMES IT WILL BE MOVING AWAY FROM YOU. ALSO, AT TIMES YOU WILL BE SHOWN BOTH DIRECTIONS OF THE EXPRESSWAY WHILE OTHER TIMES, JUST ONE LANE WILL BE SHOWN.

When you get to the Text Screen, don't explain what they should look at. If they ask, tell them to use their best judgment.

When you get to the Moving Video Screen:

THE SIDE OF THE ROAD THAT YOU ARE INTERESTED IN IS ALWAYS CLOSEST TO YOU, AS IF YOU WERE THE CAMERA PERSON. (IT IS NOT COLOR-CODED LIKE THE STILL VIDEO SCREENS). ALSO, THE PICTURE QUALITY IN THE TEST SEQUENCE IS BETTER THAN IT IS IN THIS PRACTICE.

When you get to the Graphic Screen:

THESE SCREENS SHOW YOU CLOSE-UPS OF THE TRAFFIC PROBLEM AREAS SEEN IN THE INTRODUCTORY SCREEN. AGAIN, THE COLOR-CODING OF THE SPEED OF TRAFFIC IS THE SAME. THESE AREAS ARE IN THE SAME ORIENTATION AS THEY WERE ON THE INTRO SCREEN. NORTH IS "UP."

When the practice is done:

ARE THERE ANY QUESTIONS? DO YOU WANT TO SEE ANYTHING AGAIN? IF NOT, I CAN TAKE THE CAMERA OFF NOW.

Answer questions and then remove the camera.

YOU WILL PRACTICE USING THE TRAFFIC INFORMATION DISPLAYS AGAIN, WHILE DRIVING WITHOUT THE CAMERA. BEFORE WE GO ON THE ROAD I NEED TO TURN OFF THE COMPUTERS, AND THEN WE CAN GET GOING. NOW WOULD BE A GOOD TIME TO GET A DRINK OF WATER OR USE THE REST ROOM IF YOU NEED TO. *Show where the fountain and rest rooms are.*

In the rear of the vehicle:

*Turn **OFF** the power, and unplug the blue cord. Close the trunk. Tell subject to start car, and direct them out of the High Bay. Tell them to put car in **Park**. Ask driver to adjust seat, mirrors, steering wheel, and check the gas. (Note the level if it is low). Turn on the **Inverter**, and **Internal** Power. Open the trunk and turn on the PC-VCR to channel **L**.*

*Get in the back seat of the Honda and turn **on** the Mac. Select the **Diversion** stack and then click on the appropriate **system** (same as in practice). On the PC, select **1** on the menu. (If menu doesn't appear, at the prompt, type: **Honda**.) Fill in the fields on the PC screen. Use the up and down arrows on the number pad to get to the line you want to change, hit return and then type in the name of the fields (subject name, number, condition, etc.) Remember to type in a **new filename**. Then type **3** at the menu to collect data (display data). Plug in the cable (it's unlabeled) from the front and rear cameras to the monitor.*

Leave UMTRI via Green Rd. (going left out of the UMTRI driveway). Turn right on Plymouth Rd. and then left at the sign for US-23 North to Flint. Remind the driver:

THE SPEED LIMIT ON M-14 IS 65 MPH, BUT DON'T FEEL PUSHED TO DRIVE AT THAT SPEED IF IT FEELS TOO FAST. PLEASE TRY TO DRIVE IN THE RIGHT LANE. WHEN WE GET TO A SAFE POINT ON M-14, AND YOU ARE READY, WE'LL START THE PRACTICE.

*Take the first exit off of US-23, which is M-14 East. Then, begin recording on the VCR by pressing both **Play and Record**. Also, begin collecting baseline data by typing **!**. Make sure that the Save box on the monitor is filled (and that you are not making !'s in the comments). When appropriate:*

ARE YOU READY TO START THE PRACTICE? REMEMBER THAT THE SYSTEM WILL WAIT FOR YOU TO PRESS A BUTTON TO VIEW THE DETAILED SCREENS, SO YOU CAN WAIT UNTIL IT'S SAFE TO DO SO.

*When the subject agrees, click on **Practice**. Make sure the save box is still filled. (if not saving, usually by hitting **return** and typing **!** it will save again.) When subject is finished with the Practice, remind them that we are driving to **Exit 20, Sheldon Rd.** and ask them if they have any questions. Press **ESC** on the PC to save data under the given filename. Type **Y** at the prompt to save that data.*

*At the menu on the PC, type **1** to change test parameters. All test conditions are the same, just **change the filename** (or you will write over the practice session data). Then press **3** to view data collection. Also, replace the driver and forward scene camera cables into the monitor with the Eye Camera cable (marked EMR).*

At Exit 20, take the ramp until you get to the light (in front of the Ford plant). Turn left at that light. Stay in the left lane and go under the overpass. Immediately after the overpass, turn left into the driveway with the blue sign "Plymouth Oaks." Continue on and turn left into the lot after to the first building on the left. (Find the shady spot on the far right side.) Keep the car in Park (turn off the A/C).

*Subject remains in the driver's seat. Make sure camera controller is **ON**. Experimenter moves to the front passenger seat to put on the Eye Camera. Calibrate the Eye Camera. (See separate eye camera calibration instructions.) Return to the back seat. Make sure the eye tracking bars are working (moving).*

***Immediately** coach the subject on other cars on the road and turns to take back to M-14. Turn right out of the parking lot, and right again out of the driveway. At the first light, make another right onto M-14 West (follow sign for Ann Arbor). Help the subject watch for traffic when getting back on M-14.*

When safely on the road, and up to speed, ask the subject:

ARE YOU READY TO BEGIN?

THIS WILL BE JUST LIKE THE PRACTICE, ONLY ABOUT TWICE AS LONG, WITH TWICE AS MANY SCREEN PRESENTATIONS. STAY ON M-14 UNTIL YOU'RE DONE. REMEMBER, <u>AS SOON AS</u> THE ROUTE B SCREEN IS DISPLAYED AND YOU DECIDE WHICH ROUTE TO TAKE, PRESS THE BUTTON FOR THAT ROUTE, EVEN IF THE ROUTE B SCREEN IS STILL UP.

ALSO, AFTER YOU MAKE YOUR DECISION AND THE NEXT GLOBAL DISPLAY APPEARS, IT WILL WAIT FOR YOU TO VIEW THE DETAILED DISPLAYS. SO YOU CAN WAIT TO DO SO UNTIL YOU FEEL IT'S SAFE.

*When the driver is ready to begin, press both **Play and Record** on the VCR. To begin saving data, type **!** on the PC. Then click on **START**. Make sure the Save box is filled. Drive as far on M-14 as it takes to complete the testing. (The Exit to 23 South (Toledo) is on the left, then immediately after, on the* *right is the exit to Plymouth Rd. If you miss that one take the second, on right to downtown Ann Arbor.) After subject finishes, press* ***ESC*** *on the PC, then* ***Y*** *at the prompt. to save. Press* ***Stop*** *on the VCR.*

Give the subject the option of pulling off the road into a parking lot or waiting until UMTRI to remove the Eye Camera. Help remove the Eye Camera when subject is ready. At UMTRI, put the car in ***Park*** *in the High Bay garage. Leave the car idling, until you shut down the system. Plug the car into the wall socket.*

WE HAVE A FEW MORE SHORT THINGS TO DO BEFORE WE'RE DONE HERE. CAN YOU PLEASE TELL ME HOW YOU WOULD RANK THE 4 SYSTEMS YOU SAW, IN THE ORDER OF PREFERENCE (EASE OF USE) -- FROM 1ST TO 4TH (BEST TO WORST)? *Record the rankings on the Ranking Preference collection sheet.*

WOULD YOU BE WILLING TO BUY ANY OF THESE SYSTEMS? *If yes, note which ones, and then ask:* **HOW MUCH WOULD YOU BE WILLING TO PAY FOR EACH OF THOSE SYSTEMS IF THEY WERE AN OPTION ON NEW CARS, AND COMPARABLE TO A GOOD CAR STEREO SYSTEM?** *Record prices on willingness to buy/pay form..*

NOW I'M GOING TO SHOW YOU ALL THE MOVING VIDEO DISPLAYS AGAIN, AND I'D LIKE YOU TO TELL ME WHAT YOU ESTIMATE THE AVERAGE SPEED IS OF THE CARS ON THE PROBLEM TRAFFIC SIDE (IN MPH). IF YOU THINK ALL 3 LANES ARE MOVING ABOUT THE SAME RATE, YOU CAN GIVE ME ONE SPEED. IF SOME LANES ARE MOVING AT MUCH DIFFERENT SPEEDS, THEN YOU CAN GIVE DIFFERENT ANSWERS FOR THOSE LANES. (IT DOESN'T MATTER WHAT YOUR ROUTE CHOICE IS HERE, WE JUST NEED TO LOOK AT THE SCREENS.) *Click on* ***motion*** *video system, then on* ***Start****. Record the subject's estimates on the Speed Guess sheet.*

OK! WE'RE DONE. WHILE I TURN OFF THE EQUIPMENT, PLEASE FILL OUT THE PAYMENT FORM AND YOU'LL BE ALL FINISHED. *Give participant the appropriate payment form and clipboard. Show them the parts to fill out. Clear the fields on the Mac. Change* ***subject name and number*** *on the Mac, for the next subject.* ***Eject*** *the VCR tape, and be sure it is labeled with that Subject's number. Make sure paperwork is filled in properly, and pay the subject (if not university employee). Otherwise, if U of M employee, tell participant that the amount will be on the next check. Thank the participant and walk them back out to the front door of UMTRI.*

<u>*If you are running another subject today*</u>*, leave the car plugged in. Click on the* ***next system*** *to be run first, and move arrow to* ***practice****. Lock the High Bay door.*

<u>After last subject of the day:</u> *Plug blue cord into wall outlet. Turn on power to* ***External****. Copy the data for that session off the Hard Drive, onto a floppy that is labeled with that subject's number.* ***Fill gas tank if needed!!*** *Lock the car, the garage, and the High Bay.*

Appendix B - Eye Mark Camera Calibration Procedure

1. Adjust all axis and focus knobs to the median position (for maximum adjustability).

2. Be sure cables are correctly connected from the head unit and LEDs to the camera controller, and turn on power switches.

3. On the remote, select:

Function:	EMR;
Mode:	1;
EMR:	•;
Camera:	C;
LED:	R (on);
Comp.:	1st LED (of 16).

4. Place camera on participant's head. While participant stabilizes camera, adjust overhead straps and rear clasp so that pupils are centered vertically in the goggles. The camera should be snug, so that moving the head and facial expressions do not cause the camera to slide.

5. Looking in the hand-held monitor, locate the pupil. If it is not obvious, have participant blink, or re-adjust the goggles so that the pupil is visible. Slide the focus knob on the side of the head unit so that the pupil (not the lashes) is clear. Center the pupil in the view finder by turning the X-Axis and Y-Axis knobs on the side of the head unit. Next, adjust the LEDs stem (on the front of the goggles below the eyes) so that the eye spot is at its brightest intensity on the pupil.

Adjusting the Parallax

6. On the remote, select:

Camera:	A;
Mode:	2;
EMR Spot:	+, ;
Bar:	(on).

7. On the head unit, focus Camera A on the forehead of the head unit. For this study, angle the camera down as far as possible (maximum = 15 degrees).

8. Adjust the eye mark (+) to the center of the cross hairs: Have participant angle his or her head so that the focal point is centered on an image on the view-finder (centered on the cross hairs). Then have the participant stare at that point while experimenter adjust the X-Axis and Y-Axis knobs until the eye mark is centered on the cross hairs. That is, the center of the visual field should coincide with the actual spot the participant is looking at.

Adjustment of the Electrical Magnification

9. Press the X-Up and Y-Up buttons on the remote so that the LED Comp is in the 7th position (of 16) on the camera controller unit.

10. Ask the participant to look at an object in each corner of the visual field (as seen on the hand held view finder). While participant is looking at each spot, press the X- and Y-, Up and Down buttons on the remote so that the eye mark and the spot where the participant is looking coincide.

11. On the remote, select: Bar: (off). Begin recording data.

Appendix C - Consent Form

Evaluation of Video Traffic Information

Participant Consent Form

We are working on a system to show drivers traffic information that might be in cars of the future. A well designed system can be used at a glance, so people can concentrate on driving. Responses from typical drivers such as you, will help identify the best way to show this information.

While driving a vehicle, you will be shown traffic situations on a video display. You will then choose one of two routes that you would take (by pressing a button) given the traffic situations. As you are driving, you will be wearing an eye monitoring camera, which measures your pupil diameter and indicates how interested you are in the various systems. The camera will not touch your eyes, and should not impair your vision while driving. During the study, you will be videotaped. You also should be aware that the driver's side airbag has been disabled due to the use of the eye monitoring camera.

The experiment should take less than 2 hours for which you will be paid $25.00. 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)

Appendix D - Biographical Form

University of Michigan Transportation Research Institute
Human Factors Division

Subject: ______

Video Traffic Information 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 car with a navigation system? yes no

Does your car have a Head-Up Display (HUD)?
(If you don't know what it is you probably don't have one.)

yes no ----> Have you ever driven a car with a HUD? yes no

How comfortable are you using maps?

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

How many times in the last six months have you used a map?

0-2 times | 3-5 times | 6-8 times | 9-12 times | 12 + times

How familiar are you with Metro Detroit highways?

very familiar | moderately familiar | neutral | moderately unfamiliar | very unfamiliar

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 - Complete List of System Preference Rankings, Willingness to Buy, and Price Willing to Pay for Any System.

S #	Sex	1st Sys	Text	Graphic	Moving	Still
			Rank (Price)	Rank (Price)	Rank (Price)	Rank (Price)
5	M	graphic	2 (-)	1 ($500)	3 ($1,000)	4 (-)
6	M	graphic	1 ($100)	2 (-)	3 (-)	4 (-)
7	F	graphic	1 ($200)	2 ($200)	3 (-)	4 (-)
8	M	text	1 ($400)	3 (-)	2 (-)	4 (-)
9	F	still	1 ($250)	4 (-)	3 (-)	2 (-)
10	M	text	2 (-)	1 (-)	3 (-)	4 (-)
11	M	moving	1 ($500)	2 ($500)	3 (-)	4 (-)
12	F	still	2 (-)	4 (-)	1 ($600)	3 (-)
13	F	text	1 ($450)	2 ($550)	4 ($800)	3 (-)
14	M	still	1 ($300)	2 ($200)	3 (-)	4 (-)
15	F	moving	1 ($200)	2 ($200)	3 ($200)	4 ($200)
16	F	moving	1 ($1,000)	2 (-)	4 (-)	3 (-)

Note: (-) indicates the participant would not be willing to buy the system.