Genesis
Pilot Human Factors Test
Human Factors Evaluation
of
Driver Multitasking and Message Formats

Final Report

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16. Abstract (Limit: 200 words)

The work reported here was on two separate topics. The first of these was the multitasking effects on driving performance of using pagers or PDAs while driving. The literature showed that such effects can occur but that they are task specific. Findings cannot be generalized from one task situation or device to another.

The second topic was the format for message presentation on the pager or PDA. The message formats could be improved. Improvement would result in improved legibility and comprehension and decrease the time a driver would attend to the display.

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Executive Summary

This human factors project had three objectives: (1) To prepare a concise set of human factors guidelines for evaluating devices; (2) To assess Genesis message format suitability and; (3) To provide a literature review and synthesis of human factors relating to the use of devices, such as cellular phones, pagers, car radios, cigarettes, etc., while driving an automobile; i.e., multitasking while driving.

The objective for the Driver Multitasking subsection of the Pilot Test Human Factors Report was to perform a literature review and synthesis related to the use of devices while driving a car. The main issues related to this objective are divided attention when driving, multitasking, and information processing workload. Each of these main factors was defined and discussed in the context of the Genesis Operational Test. Appendix B discusses message readability and population reading skills in the context of Genesis messages. Conclusions were drawn from this review and synthesis.

The main conclusions were that the use of information providing devices such as pagers or PDAs will increase information processing workload; that the findings from the use of a particular device under particular conditions cannot be generalized to other devices or conditions; and that only empirical findings will show whether and under what conditions, reading traffic information displayed on pagers or PDAs will seriously degrade driving performance.

In the Message Format Evaluation part of the report we reviewed message formats from the point of view of legibility, message content with special emphasis on fornnat consistency, and the hierarchical structure for message formatting. The evaluation was based on published guidelines as well as HFRL experiences with message formats for the set of traffic messages used for Radio Broadcast Data Systems. The guidelines used for the evaluation were presented in the report proper as well as other more general guidelines which are in Appendix B. Appendix C contains a list of references which discuss aspects of the display of information to users. This information

could be usefult to designers if the message formats are changed in the future. The message format discussions were based on the messages which actually appeared on the pagers or the PDAs.

We found deficiencies in all three of these areas; legibility, content, and structure. Most of these deficiencies are related to the current experimental nature of the Genesis Project and to particular properties of the hardware (pagers and PDAs) which force problems, especially in legibility. The deficiencies which we noted, while serious in the aggregate, could be easily remedied for a subsequent phase of Genesis.

General Introduction

This report covers two main topics with three appendices which cover the work performed by the Human Factors Research Laboratory for the Genesis Operational Test. The two main topics are: Multitasking by Drivers, and Evaluation of Message Formats. Appendix A contains information on guidelines for conducting human factors evaluations; Appendix B discusses display legibility and population reading skills; and Appendix C contains additional references for the design of information displays.

This human factors project had three objectives:

- To prepare a concise set of human factors guidelines for evaluating devices:
- To assess Genesis message format suitability and;
- To provide a Literature review and synthesis of human factors relating to the use of devices, such as cellular phones, pagers, car radios, cigarettes, etc., while driving an automobile; i.e., multitasking while driving.

Driver Multitasking

Introduction

Objective

At least in its earliest stages, as evident in recent in-vehicle driver aiding systems, some Intelligent Vehicle Transportation Systems (ITS) programs appeared to be adding to the attentional load associated with driving a vehicle. Examples and discussion of attentional load and driving were presented in a study published by Hancock and Caird in 1992 [1]. What we still do not know is which combinations of perceptual and motor tasks combine to overload the driver, nor do we know the outcome of either momentary or prolonged driver overload.

Drivers are often engaged in many activities while driving which seem to have nothing to do with the task of driving a car. These extra activities may be done even while driving in heavy traffic and at high speed: We see, for example, drivers eating and drinking, talking on telephones, combing hair and applying makeup using a mirror, listening to or tuning the radio, or reading a map or other printed material. What is the effect on driving performance when these non-driving activities, singly or in various combinations, accompany driving? Given the narrow attentional bandwidth of an average driver, even just driving may, on occasion, use all of that bandwidth. What happens as we overload the driver? One way to answer this question with respect to the use of Genesis devices (pagers and Personal Data Assistants, PDAs), is to compare their use while driving with the use of devices with which we are more familiar, such as cellular phones or ordinary car radios. That was our intent in this project.

Scope

This task was limited to a review and analysis of the literature which bears on multitasking and vehicle driving in customary traffic conditions. In the SAIC document, ***Pilot Human Factors Test, Detailed Test PIan,*** on March 21, 1995 this task was described as follows: "Provide a literature review and synthesis of human factors relating to the use of devices, such as cellular phones, pagers, car radios, cigarettes, etc., while driving an automobile."

In an earlier Human Factors Research laboratory (HFRL) study done for Genesis by Wade, Stackhouse and Burr-us in 1993 [2] standard human factors concerns for Genesis devices and their use were evaluated. Relevant material from that report is included here. Of special interest in the previous study was the fact that the devices to be used, were designed primarily for home and office use and not for use in moving cars. Issues of legibility and readability, especially with regard to changing luminance conditions were examined. Human factors standards were discussed but they were of only limited help since they were not specifically created to help with the in-car problem. Some general human factors considerations do apply. These are such concerns as literacy of the population of potential users, and readability and legibility of the message screens. Formats suggested by IBM were evaluated and several suggestions for improvements were made. We also included a section of recommendations regarding safety and another section on the training of Genesis device users. In all the material presented here the overriding concern was the possibility that the use of the devices in a moving car could divert attention from driving.

Literature Review And Analysis

Divided Attention Issues in Driving

One of the critical problems of driving in an Intelligent Transportation System (ITS) environment is the question of distributed attention. It is clear that the present trend is for providing drivers with increased information in the driving environment. (Devices for use inside the car such as navigational devices and personal information devices as well as information presented outside the car via ordinary signs as well as variable message signs, place greater attentional demands on the driver.) Also, we are aware that division of attention among multiple tasks leads to degradation of primary performance (steering, speed maintenance and braking), especially in high demand (i.e., congested traffic) conditions. The seminal work done by Brown and Poulton in 1961 [3] at the Applied Psychology Unit in Cambridge, England attests to these performance changes. What is as yet unknown is the relationship between the division of attention and safety in terms of collision avoidance. We do know that attention is implicated far more in driving safety than simple visual function. This accounts for the poor correlation between visual function, as measured in driver screening and licensing tests, and subsequent driving accident records. As divided attention is clearly a critical factor in safety, it is central to an understanding of how in-vehicle intelligent-traveler communication devices can be used.

Current demonstration projects (such as Travtek, Trilogy and Genesis) provide displays within the vehicle. These informational systems allow the driver to direct vision away from the road to assimilate information from the display. Safety is the putative reason why the driver cannot reprogram the route of the vehicle from the screen while the car is in motion. However, if drivers are able to change displays (e.g., for time and date), and if drivers are able to reprogram routes, then distraction becomes a problem. In fact, during driving it is frequently the case that the display becomes the center of attention and primary demands such as headway and velocity control are neglected with problematic results. Such tasks as reprogramming routes need not be done by using keyboards or other input devices. Instead, they may be done mentally; such as in deciding whether or not to take a particular alternative route when information is received suggesting that there has been an incident on the main route.

Attention takes a finite time to switch. However, models of drivers' capability show that intermittent sampling of the forward view, i.e., repeatedly glancing at the road and then glancing back at the display, does provide the capability for vehicle control. Problems only arise in unusual or emergency conditions. Quite simply, this is why we can tune radios without a collision each time. However, increasing the time attention is directed inside the vehicle increases the opportunity of collision. Fortunately drivers may behave in an adaptive manner when confronted with increasing amounts of information. Wierwille and colleagues in 1991 [4] experimentally determined that drivers adaptively shifted their attention from an in-car navigation display to the outside driving world as outside visual demand increased. In partial confirmation of this finding, Harms in 1991 [S] showed that as visual demand outside the car increased while simultaneously cognitive demand inside the car increased, drivers reduced their speed and devoted more attention to the outside world while reducing attention to the in-car cognitive task.

One potential solution, to this switching dilemma, is the use of head-up projection displays in which information can be presented on the windshield. Such vehicles are already in operation, although the information they display is non-vital and therefore represents a technical rather than human factors approach. There are, however, problems with head-up displays namely "where" to present the information in terms of focus of the driver. If the displays are focused on the windshield, then attentional capture could leave drivers as blind as if they were looking in a different direction. This capturing effect is especially true if drivers are fatigued. In this case, time is required to switch attention via switching of focus from the forward driving scene to a head-up display. If displays are focused at infinity then drivers must distinguish information from a constantly changing background and this can become as demanding an attentional task as the inside-outside switching it was intended to alleviate. In short, information presentation within the vehicle is a trade-off with attention needed for vehicle control.

Workload And Secondary Tasks

Ivan Brown and his colleagues at Cambridge University [3] showed in 1961 that doing two things at once degraded driving performance as a function of traffic density. There are also published studies using the subsidiary tasks mentioned above in realistic driving situations (such as those at the Traffic Research Center, University of Gronigen). There are also experiments such as those done by Hancock, Wulf, Thorn, and Fassnacht in 1990 [6] which use a secondary task paradigm to estimate the mental workload (as contrasted to physical workload) caused by a primary task. The primary task in the present context is driving a car. The general finding is that as the driver devotes more and more attention to an increasingly difficult driving task, performance on the primary task of driving the car, up to some difficulty level, does not change but performance on the secondary task deteriorates. However, eventually the increasing difficulty of the secondary tasks will degrade primary task performance. This is the basis for the hypothesis that secondary tasks will increase the mental workload of the driver until the driver becomes overloaded and driving performance fails. If traffic is heavy or the weather is bad, overload (exceeding the driver's attentional bandwidth) may happen with very little secondary task loading.

Multitasking

The simultaneous performance of multiple tasks is called multitasking. At the Human Factors Research Laboratory (HFRL) we are concerned with the effect of multitasking on driving performance. Congestion on highways with its high cost increasingly concerns transportation agencies. The ITS community is evaluating congestion reduction ideas. One of these ideas is to provide travelers with devices which would give them timely information for route selection, navigation and congestion avoidance. The Trilogy and Genesis programs are two examples of such evaluations.

There are human factors considerations related to the use of such in-car communication devices. This is especially true given the task loading which motorists impose on themselves. We often see drivers performing tasks alone or in combinations which have little to do with the control of their vehicle. The objective of an experiment directly related to multitasking was done by Stackhouse and Dewing in 1995 [7]. This study evaluated the impact on driving of performing representative non-driving tasks during simulated driving. The experiments were performed in the HFRL's driving simulator.

Three secondary tasks (talking on a simulated cellular telephone, finding an object in an enclosed container, and using a special radio with head-up map and text displays) were performed while driving the simulator. These secondary tasks were performed alone, as pairs or all three simultaneously. Subject drivers were required to maintain speeds of 25 to 30 mph, to keep the car centered in their traffic lane, and to respond quickly by braking on the appearance of simulated brake lights.

The subjects were divided into four groups: young females and males (31 years of age on average) and older females and males (70 years of age on average). The groups had equal numbers of subjects. Each subject performed each of the task loading conditions plus a control task twice.

The results demonstrated that age but not gender was statistically significant and that doing some of the tasks significantly degraded driving performance. The task which caused the greatest problem was the task which required drivers to use the visual display showing a map and the text of a traffic message. In this experiment drivers were free to allocate their attention among both in-car tasks and outside-car tasks. This visual display of map and text, an instance of a Radio Broadcast Data System, is one of the devices which will be evaluated in an on-road driving project. The above multitasking study showed that there were objective reasons for considering the evaluation of trade-offs between providing drivers with information requiring a high degree of visual attention and traffic safety.

In the case of human performance, each of the individual tasks such as those described in the above HFRL experiment, is called a loading task because it imposes a load on attention, cognitive function and often on motor motor function as well. Theories of human information processing generally predict that cognitive and motor performance will decrease as a function of the number of tasks being processed concurrently. However, there is disagreement as to the precise nature of this performance decrement. The classic single channel theories of attention developed by Broadbent in 1958 [8], and further refined in 1971 [9] and 1982 [10]; as well as similar theories by Treisman in 1960 [11] ,and 1969 [12] and Treisman and Gelade in 1980 [13] and by Deutsch and Deutsch in 1963 [14] and Moray in 1967 [15] and in 1969 [16] predicted substantial performance decrements in multitasking situations, arguing that human attention can concentrate on only a single task at any given time. The multiple resource theories of Allport, Antonis & Reynolds in 1972 [17] and Gopher,Brickner and Navon, in 1982 [18] often predicted much more modest decrements, since they endowed humans with the capacity for parallel processing of multiple tasks, provided that the tasks were not competing for similar cognitive resources.

Cognitive science borrows from computer science in speaking of serial and parallel cognitive processes. Serial processes are those which are performed in series, one after the other. Parallel processes are those which can be performed at the same time. Generally parallel processing is thought to be the more rapid mode because the human nervous system is thought of as having “more than one mental computer” which can be brought to bear on a task at any given time.

Theoretically it is quite possible that human attention relies both on slower serial as well as more rapid parallel processing. In that case there may be certain combinations of behaviors in which drivers can engage relatively safely, while other combinations might constitute grave dangers. In other words, the effect of doing more than one thing while driving may depend both on exactly what is being done while driving, the driving environment, and what specific driving behaviors are examined. That is, certain combinations of mental and physical behaviors may affect certain aspects of driving while having little or no affect on other aspects of driving.

The most conservative position to take in the midst of this theoretical debate is to assume a default viewpoint that drivers cannot engage in multitasking unless empirical research demonstrates otherwise. Furthermore, an empirical demonstration of the relative safety of one particular combination of loading tasks should not be taken to generalize to any other combination which has not yet been tested. One theoretically possible but practically unlikely way around the problem, would be to prevent drivers from performing loading tasks while driving.

In the Travtek project for example, it was possible to implement lockouts on the navigation-aiding device so that most functions were unavailable while the car was in motion. The car had to be placed in PARK for the device to function fully. Given the variety of informational devices which could potentially be placed in cars, providing such lockouts, while technically possible, would not be feasible. Advocates of in-car devices might suggest that such devices are no different then when a driver attempts to navigate using a cumbersome paper map. This is true but map-reading while driving is never recommended. Of prime importance is the suggestion and strong inference from manuals and operational testing that informational devices should only be used when the vehicle is stationary or to use these devices as little as possible while driving. The location of these devices within the car will be a matter of user choice although the number of prospective locations is constrained by the need to read and manipulate the device from the drivers seat.

For the Genesis Operational Test and subsequent general introduction of Genesis, we might wish for a voluntary “lockout” by drivers. That is, drivers would not choose to use their devices while the car was in motion. Effective means to achieve this abstinence have not been suggested.

With this in mind, we examined the literature to determine what kinds of multitasking driving situations had already been studied. Special attention was given to the concept of representativeness or ecological validity. In practice this means that if we conducted the experiment in both the real world as well as in our simulation of the real world, we would get nearly identical sets of results.

Prior research on multitasking while driving has often centered around the use of loading tasks chosen more for their experimental and theoretical convenience than for ecological validity. For example, Brouwer and his colleagues in 1991 [19] had subjects count the number of dots displayed in an on-screen rectangle while driving. In 1990 Liao [20] had subjects respond to colored squares, do mental arithmetic, and track cosine waves with a joystick while driving. Dewar, Ells, and Mundy in 1976 [21] had subjects respond to integers between 1 and 99 flashed on-screen. In a subsequent paper in 1993 Dewar [22] suggested that reading road signs added attentional load which could result in hazardous driving. Stephens and Michaels in 1964 [23] had subjects keep a point of light centered on a CRT display.

While such tasks may serve a theoretical purpose of loading the perceptual, cognitive, and motor systems, they are not the kinds of multiple tasks in which motorists routinely engage. Assuming that one wants to study multitasking during driving, it makes sense to use independent variables (loading tasks) and dependent variable performance measures (driving behaviors) with ecological validity in a plausible driving situation.

Therefore, the attempt here was to consider the kinds of simple behaviors in which motorists routinely engage while driving, in order to assess the effects of these behaviors on various critical aspects of actual driving behavior.

Both McKnight and McKnight in 1993 [24] and Brookhuis, De Vries and De Waard in 199 1 [25] examined the effects of using hand-held and hands-free cellular telephones. The former used a form of driving simulation while the latter group collected data during actual driving. McKnight and McKnight [24] found that driving performance was affected slightly, but statistically significantly, in subjects over 50 years of age by both casual and intense (mental math computations) phone conversations but performance was only decreased in younger subjects by intense conversations. Placing the call (dialing) required the subject to remove one hand from the steering wheel, but this decreased performance less than intense conversation on the phone or tuning the radio. Tuning the car radio resulted in about the same performance decrement as intense conversation but for this task younger drivers showed a greater decrement than older drivers.

Brookhuis, De Vries and De Waard [25] had subjects drive in both heavy and light traffic while placing phone calls and talking on the phone. Lateral position control (swerving and steering movements) decreased when subjects were talking on the phone but car following (maintaining spacing and sudden stopping) was not changed due to talking on the phone. There was no change in frequency of checking the rearview mirror when talking on the phone. There was no difference attributable to hand-held versus hands-free phone types. There were no age-related effects in these experiments. In summary this work showed that use of a cellular phone resulted in only slight changes in driving performance This contrasted with the findings (above) of McKnight and McKnight [24] and Stackhouse and Dewing's 1994 study [7].

Information Processing: Workload

Just as the prolonged performance of a physically demanding task results in fatigue and an increasing number of task errors, information processing can overload an operator resulting in errors. Ivan Brown and E.C. Poulton (1961) contributed the idea of secondary task performance as a method for measuring information processing workload. For a physically demanding task we can measure oxygen consumption or carbon dioxide production and use this measure to quantify the difficulty of the task. For information processing workload there are no such directly available and measurable variables. However, Brown and Poulton found that if a subject was asked to perform as well as possible on a task of primary importance, then when the subject was asked to perform a task of secondary importance, the number of errors on the secondary task served as a reliable measure of the information processing workload imposed by the primary task. A recent application of this idea to simulated car driving was discussed by Hancock and his coworkers [6].

The idea underlying this observation is that we can process information up to some maximum rate. Increasing the processing demand beyond that rate results in an increasing number of performance errors. Said differently, as task demand increases, thus imposing an increasing information processing workload, performance deteriorates. There is a confusion here that we strive to avoid and that is the potential confusion between performance and workload as discussed by Hancock and Caird [1]. If we measure a subject's ability to keep the car between the lane stripes, we might find that we can make this task increasingly harder to do but that up to some difficulty level there is no increase in performance errors but only an increase in workload. At some level both performance errors and workload will increase. At the lower levels of task demand, performance errors do not measure demand or task difficulty. At these levels we can use secondary task errors to measure information processing workload (task difficulty). A pertinent implication of this finding might be, for example, when a driver is in congested traffic in conditions which reduce visibility, the driver may maintain complete control of the car. The driver's workload in this instance would be high although driving performance may give no indication of the difficulty of the task. However, if we added to the driver's workload with one more task, such as reading a message on a pager or a PDA, performance might suffer severely. This would be true even though reading a pager or PDA under nominal conditions might cause no performance decrement whatsoever.

In the Genesis context the above cited differences in relative importance between primary and secondary tasks are blurred. This is ecologically valid since drivers in the real world perform secondary tasks which clearly interfere with the primary task of driving to the extent that these secondary tasks momentarily become the primary tasks. This, in effect, is having two primary tasks which in turn is likely to overload the information processing capabilities of the driver. In the Genesis evaluation, drivers are not required to use pagers or PDAs while driving, however, there is no physical barrier to prevent them from doing so.

After only limited familiarity with Genesis functionality, it is likely that drivers will realize that the messages they receive on their pagers or PDAs could help them to avoid congestion caused by current incidents with their attendant delays. This help in avoiding congestion comes in two forms: 1) route planning prior to a trip, and 2) route replaning during a trip. For multitasking considerations we are only concerned with the latter form of help. If, as is likely, drivers read the traffic messages on their pagers even if there is no immediately obvious reason for them to do so, they will quickly come to suspect that reading the messages while enroute might save them trip time and the frustration of traffic tie-ups. This may well serve as an incentive to read the traffic messages on the pager *especially* if *traffic* is ***heavy.*** This is the set of conditions which could lead to operator overload as described above with is potential for causing accidents.

An alternative and more hopeful speculation is that as workload becomes heavy, drivers will not undertake an additional secondary task such as reading the displayed messages on pagers and PDAs. This speculation is supported by the findings of Wierwille [4] and Harms [5] which were discussed above.

Conclusions

From this review and analysis of the literature we can make relevant but guarded conclusions:

- Performing tasks other than driving, while driving, can lead to information processing overload and driving performance degradation.
- Information overload due to multitasking with devices or procedures is specific to the device or procedure.
- We cannot make generalize from one set of multitasking circumstances to another when the tasks require the driver to use devices.
- Physical manipulation of the device is only a secondary problem compared to the need to divert attention from the primary task of driving when using the device.
- Based on this review and analysis of the literature we cannot state that the use of pagers or PDAs in the Genesis environment will result in seriously degraded driving performance and accidents. We cannot state that drivers will even read the displayed messages when workload on the primary task of driving is high.
- We can, however, state that if the pager or PDA is used, this will divert some attention from driving and add to the driver's information processing load.

Message Format Evaluation

Legibility

Pagers and PDAs

While this section is primarily concerned with message format, we want to make a few brief comments on aspects of the display hardware. The comments will mostly take the form of comparisons between the MinnComm Pager and the Apple Newton Personal Data Assistant (PDA). Many of these comparisons concern display quality variables.

Neither device has been optimized for the Genesis task; particularly the in-car task. The switch flipping in conjunction with the flashing green light which is required on the PDA is a good example of a feature which could only be tolerated in an evaluation environment. However, this is completely appropriate for a test of a much larger system than just a display device. Thus many of the shortcomings in pagers and PDAs during the experimental evaluation cannot be taken too seriously. However, these two device types represent the entire system to the user and they are likely to color a user's opinion of the entire system.

The pager display is much shorter than the PDA but nearly the same width. This implies that if everything else were equal, we could use the same formats as concerns display width and merely place more messages on the PDA than on the pager.

The pager is back lighted and seems to have some kind of anti-reflective glass or an anti-reflective coating on the display covering. The PDA depends entirely on ambient lighting and specular reflections are a serious problem in reading the display in changing ambient conditions; especially the rapidly changing ambient conditions experienced during driving. The contrast for the PDA is adjustable but not for the pager.

Neither display is ideally suited to the job for which it is intended. The small font size on the PDA is especially worrisome, especially when coupled to the low luminance and the specular reflections. It would be possible to take greater advantage of the PDA's larger display size. If a larger font with more spacing between words and between words and punctuation was used, the specular reflections would be less of a problem, reading times would be shortened and time of attention to driving would be increased.

The format issues which follow apply to both the pager and the PDA with the exception that more messages can be shown at one viewing on the PDA than on the pager and the system should at some future time take advantage of the increased display length of the PDA.

Legibility Variables

The main factors affecting legibility on any display media are luminance and luminance contrast, stroke width, stroke height to width ratio and symbol height. There are many other minor concerns. The fundamental ideas for evaluating legibility can be found in Appendix B and this material will not be repeated here.

For the Genesis Project the two types of displays to be examined are on store shelves awaiting use in a wide variety of applications including Genesis. The legibility for devices chosen for Genesis have been extensively tested by their manufacturers and the general public. Legibility is a concern when taken in the context of reading traffic messages when driving since this requires dividing attention between the devices and the task of driving the vehicle. Shurtleff [28] clarifies the distinction between readability and legibility which is discussed further in Appendix B. The legibility of a message on a display may be adequate at one's home or office but not in the wide range of luminance environments experienced while driving.

In the previous section we discussed multitasking and its relationship to information processing workload or, on occasions, information overload. Humans have a fixed amount of attention and it cannot be divided among too many competing tasks without causing performance decrements. In our discussion of multitasking we pointed out that drivers have been found by Wierwille [4] and Harms [5] to behave adaptively. That is, drivers did not undertake an additional task when their information processing workload level was already at a high level. This adaptive behavior probably accounts for the fact while drivers perform many different non-driving tasks during driving, they only rarely have accidents due to too finely divided attention during times information processing overload.

That people behave adaptively in no way relieves us of the responsibility for providing devices and messages whose use while driving results in the lowest possible informational workload.

Message Content

In contrast to legibility we have several comments on the message content and the ability of the traveler to understand and read the messages presented. In Appendix B, we discussed the human factors guidelines for use in the study of message content. Several of the key guidelines are:

1. Guideline: Alphanumeric characters must permit rapid and accurate human performance.
   Reference: United States Nuclear Regulatory Commission (1981), p. 6.6-1.[26]

2. Guideline: Characteristics of the alphanumeric characters should take into consideration the following criteria: a) accuracy of message identification required; b) time available for recognition or response; c) distance at which the message will be read; d) illumination level and color characteristics of the illuminant; e) criticality of the message to satisfactory and safe performance.
   Reference: Military Standard 759B, (1992), p. 32. [27]

In this section of the report we will focus our message format evaluation on three areas: Consistency, Content, and Hierarchical Structure.

Consistency

One of the most common problems noted with the message content is that the placement of various parts of the messages is not consistent. The correct format is a statement of the main message or incident, then the “From” and the “To,” and finally the duration portions of each message. These elements in this order should be consistent across each screen of message text. While we did not evaluate the frequency with which messages violated the guidelines, we do not believe we have selected unique or rare instances.

Message#l

S:I-35W S road	**line 1**
construction	**line 2**
Roadway reduced to	**line** 3
one lane From:46TH	**line 4**
ST To:36TH	**line5**
ST(07 / 12-07 / 12)(00:0	**line** 6
0-05:00).	line 7

Message #2

N:TH100 N road	**line 1**
construction right	**line 2**
lane closed From:Highway	**line 3**
55 To: HWY	**line 4**
7(0 0 : 0 5 : 0 0)	**line 5**

Both of these messages when presented on the devices should give the same information on the same line of text This will make the screens easier to read because the driver will know that the first line states the highway affected. The second, third and possibly fourth line would describe the incident or message. The fifth (or next) line would always be the "From," with the following line would always be the "To." Duration and dates would be displayed on the last two lines if necessary.

For example:
Message #3

S: I-35 South	**line 1**
Road Construction	**line 2**
Roadway reduced	**line 3**
to one lane	**line 4**
From: 46th St	**line 5**
To: 36th St	**line 6**
(7/12)	**line 7**
:00 - :05)	**line 8**

We make this suggestion based on two principles. The first is that consistency across displays or screens will lend itself to easy understanding which will improve with familiarity. If users need to know the "From" and "To" portions of the message they will be more satisfied if they know where to look each time.

In the first of the above examples there are issues of lesser importance than consistency which should nonetheless be mentioned:

- S: is both cryptic and redundant on the designation of South in the same line. It is possible that if the user is unaware that the particular roadways named in the message are in the southern sector, adding S: to the message may not be helpful. A pager user will probably know which pager slots refer to the North and which to the South. The PDA users must actually select N or S. Thus using N: and S: only add visual noise to an already difficult to read message signal.

- In line 1 of Messages #l and #2 the abbreviations of North and South are not necessary. Compare the readability of those lines to line 1 of Message #3.

- In lines 4 and 5 of Message #l there is no compelling reason to capitalize TH as in 46TH. Compare this to the readability of lines 5 and 6 in Message #3. Similarly in lines 5 and 6 of Message #l the T of ST does not need to be capitalized. Compare this with lines 5 and 6 of Message #3.

- While we strongly favor consistency, it can be overdone. The TH used in lines 4 and 5 of Message #l is to show degree, e.g., 46TH street. The TH used in line 1 of Message #2 stands for Trunk Highway and this latter usage is conventional. The conventional or stereotypical use of th to show degree is to use lower case as shown in this sentence. Understanding is usually enhanced if we conform to a population stereotype. The contrary use of a stereotype (for example, having red mean go or safe) is always confusing.

- A frequent problem with message format is improper line-wrap. For example in lines 4 and 5 of Message #2, the 7 which begins line 5 actually should be the last character displayed in line 4. That is the 7 belongs to HWY; it is not a prefix to the first time given in the duration.

- The last lines in Messages #l and #2, the date and time lines do not need to use the left-most zeros. The date need not bne inclusive since the action takes place on just one day. Message #3 suggests an alternative method.

- Another form of the line wrap problem is the failure to use a consistent format for the assignment of message elements to particular lines or at least to a particular ordering of the message. Following Message #2 is a discussion of this problem which could be amended by the considering an ordering of elements instead of rigidly assigned line numbers. For example, in Message #2 if the name of the affected highway was so long that two lines were required, then two lines should be used. However, the ordering of the subsequent elements should not be changed, only the line numbers. Also, each element should begin on its own line. Message #4 illustrates how to decrease readability by a crowding a message into a single line.

- Another instance of improved consistency might be the use of a spelling checker before the message is transmitted.

- The From/To format change was added for good reasons. However, consistency in this regard can lead to messages conjuring up strange mental images. From/To is appropriate for a messages like "traffic congestion cleared" or "stop and go traffic". However, for messages such as "disabled vehicle" or "accident cleared" using designators such as Between/And might serve to reduce our inclination to imagine mile long vehicles or mile long accidents. Between/And also works well for the messages appropriate to From/To and the colons after From and To are not need with Between/And.

Message #4

S:I-35W S disabled vehicle From: 90TH ST To: 94TH ST

Message #5 shows an alternative and more readable format for presenting the same information shown in Message #4:

Message #5

I-35W South
Disabled vehicle
Between 90th St
And 94th St

Note that spaces have been added between the colons and the first digits of the street numbers. This too adds to readability as does the adoption of the other changes suggested above.

3. Guideline Consistency of messages should follow these guidelines: a) words should be spelled correctly; b)messages should maintain consistency within and across screens in their use of words, acronyms, abbreviation and format. Reference: U.S. Nuclear Regulatory Commission (1981) p. 6.6-11, 12 [26].

The first point referred primarily to consistency. The second point is made because of the device's functionality. The pagers use four lines of text per screen. These pagers scroll by screens of four lines of text. If every time that the pager scrolled, a user could receive consistent information, then there would be less confusion and less searching for pertinent information. If users know that each time the display screen scrolls, they will get either the message information (such as incident information) or the location/duration, they will use the device more effectively. Currently, the message is shuffled and it is difficult to recognize information type without studying the entire message carefully. The following shows an example of consistent displays. Successive screens of text would demonstrate consistency by repeated use by placing message information on the first screen and duration information on the second screen.

Screen 1	Screen 2
I-325W South	From: 46th St
Road construction.	To: 36th St
Roadway reduced	7/12 - 7/12
to one lane.	:00 - 5:00

One of the causes of this problem is the syntax used in the messages which provides no Carriage Return (CR)or New Line (NL) between components and the fact that no text spaces exist between the From, To (Between, And), and duration portions of the message. The devices should keep words from being broken because as they do, the messages fail in their attempt to provide information clearly. Examination of Message #l shows that lines 5,6, and 7 are one long run-on word with no space between 36TH ST and (07/12-07/12). Likewise, there is no break between (07/12)(00:05). This causes the device to attempt to keep "words" together which in turn results in these broken phrases.

Exacerbating the difficulty is the short time allowed for a user to read a screen of information on the pager. The pager allows the user only about 4.5 seconds to read the screen. This can cause the user to reread the same screen, probably several times especially if engaged in driving, just to have adequate time to read the entire screen. The amount of time required to display and read and then redisplay and read the rest of the message is probably more time than just adding about two seconds to the time a screen is in view, avoiding the need to redisplay the same screen.

Message #6 provides another example of the problems just mentioned:

Message #6

N: I-94W road
construction
From:HENNEPIN/LYNDALE
E AVE S To: 11TH ST
S(O7/12-07/13)(22:00
-24:00)

The inability to correctly parse the message is evident. It is difficult to interpret a line that states: "E AVE To: 11TH ST." Likewise, on several occasions we have noted lines of text that have only one word or even a single character because the next word is a large complex of unbroken words which the system is unable to parse correctly.

4. Guideline: Capital letters should be used only for very short messages. If the message has several long lines of text, upper- and lower-case letters should be used. Bold faced letters or capitalizations should be used only for short words or phrases that require emphasis.

   Reference: Military Standard 759B, (1992), p. 323 [22].

Another area of concern already mentioned in passing is the over use of capital letters. Capital letters should only be used in a manner consistent with contemporary English language. These messages are not newspaper headlines and should not follow the practices used by newspapers. The conventional use of capital letters results in text that is more readable than using all capital letters as shown by Shurtleff in 1980 [28]. The intent is not clear regarding capitalization of all the letters in the location words but not using capitalizing for any of the message's information words. It is inconsistent to capitalize only the first letters in "From" and "To" and yet to capitalize all the letters in the words which follow. The "From" and "To" nearly disappear from view in the forest of capital letters which follow them. Rewriting Message #6 could yield Messge#7:

North: **I-94W**
Road construction
From: Hennepin/Lyndale Ave S.
To: 11th St S
7/12-7/13
22:00-24:00

Note the increase in readability. Note too that placing time and date on their own lines obviates the need for parentheses. Perhaps delimiters of some sort are needed as an aid in parsing. However, delimiters such as parentheses, need not be transmitted to users.

5. Guideline: Use whole words instead of abbreviations wherever space permits. If abbreviations are used, create a standard list of abbreviations that are appropriate for the system users. Acronyms should be used sparingly and only if their meaning has been well established.
   Reference: Woodson, Tillman and Tillman (1992), p 369 [29].

6. Guideline: Words and phrases should be chosen on the basis of user familiarity whenever possible, provided the words or symbols express exactly what is intended.
   Reference: Military Standard 759B, (1992), p. 326 [27].

Representativeness

We also examined message content to establish whether the messages are conveying an accurate description of an incident to a user. We could not conduct any extensive testing of the message content using subjects. Therefore, our evaluation depends on guidelines and suggestions on message content from our own examinations.

Abbreviations were used sparingly in this database and the abbreviations which were used are very familiar. This is good for reading comprehension. We should note that the database uses ST for Saint and in Saint Anthony Boulevard, as well as ST for street. This could cause confusion although context will usually greatly reduce the opportunity for confusion. Always avoiding the abbreviation for “Saint” would eliminate confusion.

In a previous study of RBDS systems HFRL noted that messages should contain easily recognizable phrases and common names of streets. The Genesis system does not use common names but uses the standard Department of Transportation (DOT) terminology for routes. This can cause confusion because most drivers do not know that TH 62 is Trunk Highway 62. They know it as “62-the Cross-town Highway” or more briefly, the “Crosstown.” When the message includes, "TH100N" very few people will think “Trunk Highway 100 North. Most will recognize 100, but the other characters cause delays in reading and comprehension. (As noted earlier correct spacing would also improve legibility.) Ideally, the databases would contain the ability to translate DOT designators into names more familiar to users. Users will more rapidly comprehend the location of an incident if the message states “Cedar Ave South”, rather than “SH77S.” Simply stating “100 S” or better “100 South” will result in more rapid comprehension that will "TH100S."

Notation for Time

We have previously mentioned problems with the way durations are expressed. The military format for a 24 hour day is fine for those few who are familiar with this convention. However, many would be confused by this convention and many more would need to subtract 12:00 from 15:30 to arrive at the more familiar format of 3:30 PM. In this example, the use of the military format saves only one character of display space. Such slight savings may not merit the use of the less familiar military format.

Hierarchical Structure

Hierarchical structure was mentioned briefly in the discussion of consistency. However, hierarchical structure deserves special mention due to the nature of the message structures used in Genesis.

7. Guideline: A hierarchical message scheme should be used to reduce confusion, operator search time and redundancy. This should be consistent throughout the screens or lines of text.

Reference: U.S. Nuclear regulatory Commission (1991), p. 6.4-l [26].

8. Guideline: Hierarchical messages should follow these guidelines: a) Major points or the most important information should be used in the first line of text; b) Subordinate information should follow and should identify subparts or functional grouping of the next most important information; c) Later message information should not repeat information contained in high-level text.

Reference: U.S. Nuclear Regulatory Commission (1981), p. 6.6-2 [26].

Messages must convey information on several levels and must adapt to the needs of all users. Most users will want to know What, Where, and How Long. Perhaps some users will only want to know Where. In a study to determine what kinds and how much traffic information drivers would want in order to make response decisions based on traffic messages, Dewing and Stackhouse in 1994 [37] found that messages should contain accurate, timely, quantitative and imperative information. That is, drivers prefer to receive a considerable amount of information and advice before electing to (or not to) take an alternative route. This finding suggests that message content should not be unduly abridged although is reasonable to expect that different users will want different information. By using a hierarchical structure we can insure that users will know where the particular information of interest to them can be found. It also allows for the most critical information to be given first. We did not determine test subjects' preferences in this project for order of presentation of information elements. We can, however, assume that users will first want to know Where. If the Where does not affect the users, they can safely ignore the remainder of the message. The first part of Where is the sector; either North or South (for the

PDA). The second part of the Where information contains the "From/To" fields. If users can conclude that the Where of the message may affect them they will then be interested in the What. (If the information type includes a Duration field users will then consult this field.) In this way, users can begin to make decisions on their subsequent routings.

Hierarchical structure lends itself to consistency by providing the user with the critically important information in the order wanted for each message. Search times are reduced and the users can retrieve only those bits of information wanted. They are not required to read the entire message to find the information they desire.

Although not seen as a problem with the database, we should note that information at the end of a message should not be redundant on information already given. The ability to re-read messages makes redundancy unnecessary.

Conclusions

We reviewed message formats from the point of view of legibility, message content with special emphasis on format consistency, and the hierarchical structure for message formatting. We found deficiencies in all three of these areas. Many of these deficiencies are related to the current experimental nature of the Genesis Project and to particular properties of the hardware (pagers and PDAs) which force problems, especially in legibility. Almost all of the deficiencies which we noted are easily remedied.

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APPENDIX A

HUMAN FACTORS GUIDELINES FOR CONDUCTING DEVICE EVALUATION

Appendix A

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Appendix A

List Tables

The first consideration shown below is a comparison of visual with auditory output. This addresses the "what kind of device to use" rather than the "what device features to use" question. Clearly there is a trade-off between devices with visual output and devices with auditory output. The following comparison is included as a form of guideline which could be used in selecting a single communication channel.

Visual versus Auditory Output for Communication Devices

When to Use Visual Communication	When to Use Auditory Communication
When the message is very complex.	When the message is simple.
When the message is long.	When the message is short.
When the information deals with location in space.	When the message does not necessarily need to be referred to later.
When the message does not necessarily call for immediate action	When the message deals with the occurrence of events in time (e.g., when user needs to finish some other task)
	When the message calls for immediate action.
When the auditory system of the user is over burdened.	When the visual system is already over-loaded.
When acoustic noise is too great to hear aural messages.	When the intended receiver cannot look at a visual display.
When the device will remain in a position where the user can continue to watch the display.	When the environment is too bright to see a visual display.
When the information characteristics cannot be reliably described by words.	When auditory information would be beneficially redundant.

General Criteria for Controls

The following guidelines for controls are general and include devices of the kind which pertain to the Genesis evaluation.

Control Locations

The type of controls selected for use on the Genesis devices should take into account all reasonable locations and motion envelopes to assure that users (with applicable 5th and 95th percentile body dimensions and 5th percentile strength) can operate them.

Reference: Military Standard 759A, (1981), p. l-1 [31].

Control Effort

Controls should be selected and distributed so that none of the users limbs or digits will be overburdened or fatigued through prolonged use.

Reference: Military Handbook 759A, (1981) [31], p. 1-1, Military Standard 1472D, (1989), p. 67 [30].

Control Selection

The following basic factors should be considered in control selection and full consideration must be made for the control's function, purpose and importance to Genesis including:

a) The nature of the controlled object, the type of change to be made, as well as the extent, direction and rate of change.

b). The information the operator needs, including requirements for locating and identifying the control, determining its setting, and sensing any change in its setting (feedback).

c). The amount and location of space where the control can be placed.

d) The importance of locating the control to ensure proper grouping or proper association with other related controls and displays

Reference: Military Standard 759A, (1981), p. l-3 [31].

Control Tvpe

The type of control selected for use for Genesis should take into account the following factors:

a) Operation should be possible by both right and left handed users.

b) Design considerations should include the mobility constraints of special clothing e.g. gloves or mittens.

c) The controls should be operable using only one hand:

d) The control should be chosen as though it were an extension of the operator's limbs; it should be operable in terms of the natural motions of the arms, wrist, and finger.

e) Control actions should not require awkward or unnatural positioning.

f) The control and interface should give the user constant feedback so that the operators know at all times what their input to the control is accomplishing.

Reference: Military Standard 759A, (1981) p. 1-3 (a-b) [30]. Woodson, Tillman, and Tillman, (1992), p. 424. (c-e) [29].

Control Movement

Control movement should conform to those shown in Table A-l.

Reference: Woodson, Tillman, and Tillman, (1992), p. 433 [29].

Comment: More complete discussions of control movement recommendations can be found in Woodson, Tillman. and Tillman, (1992), pp. 432-433 [29].

Table A-l. Control Movement Recommendations.

To Do This:	Move the Associated Control Device Like This:
Turn the function ON	Up, right, forward, clockwise, pull or push
Turn the function OFF	Down, left, rearward, counter-clockwise, push or pull
Move the pointer on an associated display to the RIGHT	Clockwise, right
Move the pointer on an associated display to the LEFT	Counterclockwise, left
Move the pointer on an associated display to the UPWARD	Up, back
Move the pointer on an associated display to the DOWNWARD	Down, forward
Cause an increase in the controlled function	Forward, up, right, clockwise
Cause a decrease in the controlled function	Rearward, down, left, counter-clockwise

General Principles for Selection of Visual Displays

Woodson, Tillman, and Tillman, (1992) [29].

- "Use the simplest display concept commensurate with the information transfer needs of the operator. The more time it takes to read the display because of complexity, poor viewing conditions or poor legibility due to poor display quality, the more time it takes to read and interpret the displayed information and the more apt the operator to misinterpret the information or fail to use it correctly."

- "Use the least precise display format that is commensurate with the readout accuracy actually required. Requiring operators to be more precise than necessary only adds to the information processing load placed on the operator and will add to fatigue ultimately causing them to make unnecessary errors."

- "Use the most effective display technique for the expected viewing environment and operator viewing conditions (lighting, acceleration, vibration, operator position, mobility restrictions, etc.). Match the display to the operators constraints; do not make the operator match the display."

- Optimize the following display features, Woodson, Tillman, and Tillman, (1992).[29]:
  - Visibility Viewing distance in relation to size, viewing angle, absence of parallax and visual occlusion, visual contrast, minimal interference from glare and adequate illumination.
  - Conspicuousness Ability to attract attention and distinguishability from background interference and distraction.
  - Leeibility Pattern discrimination, color and brightness contrast, size, shape, distortion and illusory aspects.
  - Interpretability Meaningfulness to the intended observer within the viewing environment; requirements for interpretation, extrapolation, special learning and training; and general reliability in terms of retention on meaning.

Direct Manipulation

When a clever designer can create a visual representation of the world of action, the users' tasks can be greatly simplified by allowing direct manipulation of the objects of interest. By pointing at visual representations of objects and actions, users can rapidly carry out tasks and immediately observe the results.

A method that in recent years has started to dominate the interface market is direct manipulation (DM). This style of design provides the user with the impression that they are manipulating the items seen in the interface directly. Several devices now exists that provide DM. The selection of the tool depends upon the Human-Computer Interface (HCI) presentation of information chosen and the integrated requirements of the user and the task.

The devices listed below will allow the user to interact with the human computer interface by using direct manipulation.

Action Buttons

Buttons should be used throughout Genesis to provide users with important clues as to what actions are available and appropriate for a given window. Labeled buttons are used for maximum visibility for actions that perform the fundamental functions of the device. Buttons are considered to be more obvious to novice users than such methods as pull-down menus. However, actions that may be considered to be supplemental or more advanced can be made available (although not necessarily in Genesis) from pull-down menu selections. This design can provide the necessary flexibility for one set of windows to support both novice and experienced users. It is likely that the novice users will take advantage of advanced features, if they are available, once they begin to explore the various options on each window. Placement of buttons needs to be consistent from window to window so that users could find them more quickly. The buttons can be of the “softkey” type. That is, they appear on the screen and are addressed via a hard key or button or an on-display cursor controlled by hard keys or buttons.

Standards for Push Buttons: A control containing a button representing an action choice or routing choice that will be activated when a user selects it.

- Use an action button in a window with a menu bar (a horizontal string of icons representing choices) to provide convenient access to a frequently used action choice or routing choice. The icons should be coded to indicate the function they represent.
- If a menu bar is not provided in a window displaying a view of an object, place action and routing-choices on push buttons in that window, except for those choices that appear on the system hardware or software “menu.”
- Avoid placing setting choices on push buttons.
- If one push button in a field is typically used most frequently by users, make that push button the default push button for the field.
- If the cursor is on a push button, make that push button the default push button.
- Assign the default push button according to the position of the cursor. For example, when a user moves the cursor to a control with associated push buttons, assign one of the associated push buttons as the default push button.
- Avoid using a push button to change the size of a window; instead, allow a user to choose the size of the window using the size borders. For example, do not provide a push button labeled “Greater” to allow a user to enlarge a window.

Other Direct Manipulation Devices

Table A-2 summarizes salient characteristics of direct manipulation devices other than buttons.

Table A-2 A Summary Table of Devices That Provide Interaction with The Human-Computer Interface.

Device	Uses	Recommended for:
Mouse	Point; Select; Draw; Drag: Move Cursor	Tasks requiring little keyboard use
Fixed function keys	Frequent or critical functions	Continuously available, important functions
Light Pens	Move cursor; Select; Draw	Infrequent use; Tasks with little keyboard use
Voice Entry	Enter numbers; Initiate predefined actions	When hands or eyes are not free
Joystick	Track; Select; Move cursor	Tasks with intensive cursor positioning
Keyboard	Select: Enter text; Enter numbers	General purpose entry device
Dataglove	3-D direct manipulation	3-D environments

Table A-2 was adapted from C. Marlin "Lin" Brown (1988) [33]. Table 8.2 Control Devices. In Human-Computer Interface Design Guidelines, Ablex Publishing Corporation.

Location of Vehicle Controls and Displays

A study by Laux and Mayer in 1991 [34] looked at the effect of the location of controls and displays on the driving task. While their study was concerned with conventional controls and displays in cars, some of their findings apply to the use of pagers and PDAs in cars.

One of these findings was that drivers, even in unfamiliar cars, have expectations about the locations of displays and controls which aid in finding them while driving. Since Genesis devices can be placed anywhere in the car, the beneficial effects of locational expectations will be reduced. Although there were no differences in locational expectancies between younger and older drivers, the older drivers did take longer to find controls placed in unfamiliar locations. They found that different display and control layouts imposed different attentional loads on drivers as they searched for controls and displays while driving and this finding was especially prominent for older drivers.

The Laux and Mayer study clearly showed the advantages of having standard (familiar and expected) locations for displays and controls. We cannot expect that all Genesis users will always locate their devices in the same location. We can also expect that a device placed on a car seat will move in accordance with the forces acting on it. This will not be an advantage for Genesis users.

In a follow-up study by Mayer and Laux in 1992 [35] the use of in-car displays by older drivers was studied. In this study different types of displays and the use of color in displays was tested. This study essentially confirmed previous findings that older drivers have more trouble in dividing their attention and that they have slower response times in both acquiring information from displays and in responding to it.

APPENDIX B

DISPLAYED MESSAGE READABILITY AND POPULATION READING SKILLS

Appendix B

Displayed Message Readability And Population Reading Skills

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Displayed Message Readability And Population Reading Skills

In HFRL's 1993-1994 evaluation of the Genesis operators' and user's display screens we reported on the ability of the population to comprehend the text displayed. We have no data to show the reading skill levels of that part of the U.S. population which has pagers or PDAs. However, we do know that marginal or poor readers will require longer times to assimilate the information on the display than facile readers. If this assimilation is occurring while the less-skilled reader is driving, more attention will be devoted to the display and less to the road.

The material on literacy which follows is based on an 1993 HFRL Genesis report by Wade, Stackhouse and Burrus [2].

Evaluation of Literacy Levels.

Newspaper accounts of the failure of our educational system to train our students adequately is a cause for concern in the Genesis project. We read that most high school students have not mastered reading; that most cannot read maps or bus schedules and that only a few can name the states bordering their own. Such reports suggested that we should be concerned with the ability of U.S. drivers to extract quickly and correctly the meaning of messages printed on their computer screens. On the other hand, it might be that only the literate segment of the population would be interested in owning a pager or a PDA device. If this is true, literacy is not an issue. However, since we have no evidence to support rhe supposition that only the literate will use Genesis devices, we should consider the state of literacy in Minnesbta and in the entire U.S.

In the congressionally mandated series of studies performed under the U.S. Department of Education, National Center for Educational Statistics as a part of the longitudinal National Assessment of Educational Progress (NAEP) [36] is information on literacy which is relevant to the understanding of Genesis-supplied information by the driving public.

> The NAEP report divided students at three grade levels into categories. We will only consider 12th grade students in this report. The first set of descriptors were for the categories covering what experts in the field believed students *should* achieve for each grade level. These were referred to as Achievement Levels. The second set of descriptors were for what students at each grade level *actually* achieved. These were referred to as Anchoring Descriptions.

- Basic Achievement Level. Should be able to demonstrate an overall understanding and make some interpretation of text. Should be able to relate aspects of text to its overall meaning, make connections among and relate ideas in the text to their personal experiences and draw conclusion.

- Anchoring Description for Basic Level. Students could develop interpretations from a variety of texts. They understood overall arguments, recognized explicit aspects of text elements and supported global generalizations. They were able to respond personally to texts, and use major document features to solve real world problems.

- Proficient Achievement Level. Should be able to show an overall understanding of the. text which includes inferential as well as literal information. Should be able to extend the ideas of text by making inferences, drawing conclusions and making connections to their own personal experiences. Connections between inferences and the text should be clear, even when implicit.

- Anchoring Description for Proficient Level. Students integrated background experiences and knowledge with meaning from a variety of texts. They could interpret character's motives and differing points of view. They could identify text structure and apply document information to solve complex problems

There was a third level called Advanced. This level was an extension from Proficient. However, only 3 per cent of students attained this level. For this reason and since those who did achieve the Advanced Level would not have literacy problems, we will not discuss this level.

Table B-l shows summary data taken from the NAEP report for 12th graders.

Table B-I Reading Levels for U.S. 12th Graders

Unable to achieve Basic Level	25%
Basic Level but not Proficient Level	38%
Proficient Level but not Advanced Level	34%
Advanced Level	3%

The data in Table B-l strongly suggests that at least 25% of the U.S. driving population may have difficulty reading Genesis display screens and messages with adequate understanding.

We might believe that anyone who is licensed to drive is literate and that everyone who drives is licensed. If we hold this belief we should moderate it by considering that only a slight attainment in literacy is required to become licensed. According to Rosemary Parks, an expert in reading education at the University of Minnesota, those who are barely literate at the 12th grade do not become more so with time. This segment of the population does not continue school. In discussing the literacy of licensed drivers, we should also consider the help an applicant might receive from a friend in completing drivers license application forms. We should also consider the fact that some drivers were never licensed and that some who once were are no longer. Another factor of concern is people for whom English is their second language and only a recent acquisition.

We do not know how many people with weak reading skills will use pagers and PDAs. We do know that poor readers will devote more time to reading and thus less time to driving. We also know that there is a difference in reading time for such tasks tuning a radio or dialing a cellular telephone as compared to reading Genesis text on a PDA or pager. Perhaps poor readers will not attempt to read text while driving.

Evaluation of The Appropriateness of Information Received by The Users And The Modes for Presenting Information to Users.

In this Subsection there are two separate issues. The first issue concerns the impact of the message on the traveler and the second the means by which information is received by the traveler.

Of immediate relevance to the former issue is work which is in progress at the HFRL. We have completed a questionnaire-based study aimed at determining the correct structure for traffic messages. In this case "correct" means, determining the message structure which causes most travelers to behave in a consistent and rational manner. Rational here means behaving in a manner which would benefit the selfish interests of each individual and thus act in a way to reduce congestion for all travelers. For example in the HFRL study done by Dewing and Stackhouse in 1994 [37] of 164 participants we found a positive correlation between amount (and type) of information and traveler responses. Participants suggested that they were more confident that the information and advice was correct and timely, the more information and advice they received.

Partially related to the literacy issue, but also related to the shortage of display area, is the use of icons to replace text. Potter, Kroll, and Harris in 1979 [38] conducted an experiment to test if people could understand and remember sentences composed of simple, single words flashed on an oscilloscope screen at the rate of 12 words per second. They found that people could do this well with normal sentences. What was surprising was an auxiliary experiment where Potter substituted line drawings for the concrete nouns in the flashed sentence. This switch had very little effect on reading or comprehension of the sentence. This implies that pictures and words are read the same way. Earlier studies by Clark and Clark in 1968 [39], and Oldfield and Wingfield in 1965 [40] suggested that the effectiveness of pictures to replace words was dependent upon how representative the picture was to its intended noun. Complexity or confounding icons reduced comprehension. Dewar in 1993 [21] conducted a study to prove that simple graphic symbols used on traffic signs were more effective than words on signs. Symbols on signs were standard iconic representations of roadway conditions, warnings, or rules. If icons were properly designed they were recognized or understood more quickly than word messages describing the same conditions.

The application to the Genesis screens and menus could be the use of icons on the Main Screen to easily lead the novice user to the screen they want, or in designing buttons that convey meaning across all screens. For an example the Help button may be represented iconically as a Question Mark, the Cancel as an Eraser, or the Save button as a Bank Vault Door. By using these icons the designer can place these buttons wherever they want them and the user will notice quickly where they are on a screen.

In this way, the need for consistent placement of all recurring buttons on each screen is eliminated. The user is not required to read each button separately on every screen which can take extra time. The user simply glances at the screen and sees the needed icon.

Initial development of icons is extremely important because of the need for the icon to represent the idea and concept for which it stands. The more abstract a concept is, the harder it will be to find an icon for it. The final point made here is that screen resolution has an effect on icons and with the Genesis devices the resolution may not be great enough to use complex icons, only the most basic or miniaturized version may be possible.

In 1993 Zaidel and Noy [40] discussed advances in three types of drivers' displays: Integrated computer-based instrumentation, head-up displays, and auditory displays and controls. They point out problems with visual displays including virtual displays. These problems center on consideration of the rapid changes in accommodation required at different accommodating distances as well as shifts in the resting status of vergence. Night driving and aging add importance to these issues. The adoption of general purpose displays and controls that either are, or function like, menu driven computer screens with select and click operation will be more susceptible to human memory and cognitive limitations as well as to interruption effects. Zaidel and Noy stated that there were no ergonomic criteria for deciding which functions should be integrated and which would be better left as dedicated instruments. In Genesis the devices may be used to support many non-traffic applications .

Zaidel and Noy [41] also stated that the auditory mode is becoming more important for advanced driver displays and controls. However, they point out some of the negative implications of using speech in a vehicle's noisy environment and for the driving population with speech and language difficulties. They also point out that the auditory mode may be more intrusive than many would want. They concluded by calling attention to the rapid rate of evolutionary change in advanced driver technologies and the need for human factors to take best advantage of these changes.

In a 1991 simulation study Brouwer and coworkers [19] compared four types of route guidance systems. They compared paper maps, head down electronic displays, head up displays using an electronic map, and voice guidance with an electronic map. Perceptions and preferences, workload, and reaction times were measured. Subjective workload, user perceptions, and the number of guidance errors indicated that voice performed the best followed by the head up display, the head down display, and finally the paper map. As one might expect the maps requiring serious diversion of attention from driving were the worst performers. The reaction time study yielded inconsistent results except for the largest reaction times being associated with paper maps. This indicated that the safest and most effective systems were those closest to the driver's field of driving vision, with several modes of communication being used simultaneously. Combining voice with maps or using projected heads up displays reduced the workload on drivers and increased their subjective satisfaction.

Summary of Previous Genesis Design Phase Recommendations

Evaluation of Messages for Legibility.

The purpose of this task was to evaluate the ability of the users to read the screens at reasonable distances and viewing angles. We were also interested in defining luminance conditions related to readability and the extent to which vision can be impaired without losing readability. Readability, according to Shurtleff [28] "denotes the reading of words and text and refers specifically to the functional relationships existing between the properties of words and text and the observers' accuracy and/or speed in reading worlds or text." Legibility by contrast "denotes the identification of single symbols, and refers specifically to the functional relationships existing between the properties of individual symbois and the observers' accuracy and/or speed of identifying those symbols."

The chief factors affecting legibility on any surface are luminance, luminance contrast, stroke width, symbol height-to-width ratio, and symbol height. Frequently in human factors we have attempted, successfully, to aid display designers and in turn this aids display users. For Genesis use at home or office we need have little concern about legibility. The legibility of small computers' or pagers' displays will be satisfactory even if for some of the less expensive display implementations this satisfaction is marginal. An example of the latter would be a dimly back-lit liquid crystal display in a low illuminance environment. Similarly, if this same display was viewed with sunlight from a window falling on it, it would again not be adjudged satisfactory.

Since in the Genesis evaluation, drivers may elect to use computer displays that have no special features allowing them to adapt to constantly changing luminances, we must expect some loss of legibility of displayed text. Shurtleff [28], extensively discussed factors which affect legibility. However, nowhere in that work is there a discussion of the legibility of a display placed on a car seat beside a driver. In this environment the most critical of the variables affecting display legibility was probably luminance. Too little ambient light at twilight or dawn, and too much light when the sun is shining either on the display or in the driver's eyes. Most of the contrast, both luminance and color, is lost and again the display may prove to be illegible. In both these cases the driver may elect to release the steering wheel with one hand and reach over and rotate the screen to a more favorable position *vis a vis* luminance conditions. The driver may now be able to see the screen. However, this will introduce parallax which will be a new factor for making the screen less legible.

Considerations such as our lack of hard knowledge and our reasoned guesses about potential traffic safety impacts are somewhat discomforting. We do know that on occasion we drive into the sun while it is low on the horizon and that this may be a difficult driving task, especially in rush hour traffic. We can guess that drivers will try to solve the luminance problems posed above by holding the device closer to the eyes than the arm's length distance to the passenger seat and to hold it at the most favorable angle for legibility with respect to the direction of the source of the ambient illuminance. We might surmise that many drivers will not respond to the cues which tell them that there is a new message awaiting their attention. Displays which have high luminance and high contrast settings are preferred as are displays with anti-reflective coatings.

Minimally acceptable contrast ratios for symbol identification (legibility) are in the range of 1O:l to 20:1 but these values are influenced by overall luminance, size of symbols, symbol blur, glare and many other factors which may or may not be present. Higher contrast ratios do not of themselves degrade legibility. However, at high contrast ratios other effects such as halation or radiation may take over thus reducing legibility. The effect of contrast on rate of symbol identification; that is, how fast a string of symbols can be read correctly is about the same as that for simple identification. Unfortunately, most computer (display) manufacturers assume reasonably good and reasonably constant viewing conditions. If the display is difficult to read, for example bright light shining on the display, it is the user's responsibility to shield the display. The small displays which are of interest for the Genesis application do not accommodate to the widely varying ambient luminance conditions.

Much the same can be said for other display factors regarding in-car use. For example, horizontal symbol spacing is usually around 10 per cent of symbol height. However, in difficult viewing conditions, spacing should be on the order of 25 per cent. Such customized display parameters are generally not available on the devices which Genesis users will buy.

Symbol size and symbol aspect ratios (ratio of symbol height to symbol width) should be large; larger than most users would prefer for say word processing at their desks. Most displays have an aspect ratio of about 3:4, height-to-width. This should be satisfactory for Genesis applications. Of greater concern is the total size of the display. We prefer that the driver obtain the maximum information possible in a single glance at the display. (We have already considered this in our discussion of icons.) There could be problems with small displays of say 8, 12-point characters by two lines. This might, at least occasionally, require scrolling which would in turn increase the time and complexity of the secondary task.

We of course hope that drivers do not attempt to use their Genesis devices during times when traffic or other aspects of the environment are imposing a high workload on the driver. We lack systematic data on when drivers attempt to perform secondary tasks when driving. From anecdotal evidence related to accidents and perhaps from introspection, we know that drivers, at least infrequently but at their own discretion, attempt to do far more information processing than they can handle safely. We do know from simulation studies by Hancock, Chrysler and Stackhouse in 1992 [42] that when drivers were required to perform secondary tasks such as speaking on a simulated dash-mounted cellular telephone, both primary task error (steering, measured by rms tracking error) and reaction time to brake lights increase. In this case the drivers, who were the subjects in the experiments, were not free to choose when they would perform the secondary task. Instead they were required to talk on the telephone at a cue from the experimenter.

Display Readability

Most interfaces and systems provide the user with an unlimited number of fonts and size ranges. Anthropomorphic data has established that there are absolute limits to the perception by the eye of font sizes and types. These limits have been tested and correlated with user ease of comprehension. Fonts must fit into the normal angular field view of the eye:

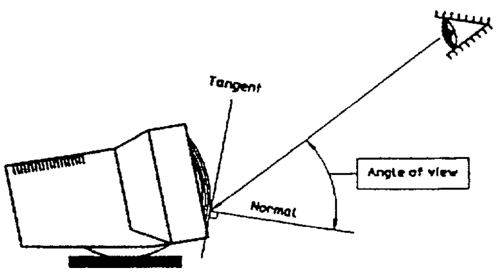

Figure A-I. Relationship of the eye's angular field of view and font size.

- A display should be legible from any angle of view up to at least 40 degrees from the normal viewing surface.
- Visual angle depends on the formula relating size and distance:

$$§ = 2 \tan^{-1} [h/2d]$$

where

§ = Visual Angle
h = Height of object and d = distance to screen[44]

Text sizing and typography have been studied more than any other area of interface design. The following represent standards for text sizing and screen placement considerations.

- Text should be at least 3.5 mm tall for optimum viewing at a 40 degree angle maximum, this corresponds to a minimum of 12 point type.

- The DIN (Duetsch Industrie Normen) specifies a minimum of 2.6 mm high based on a viewing distance of 500 mm and a range of 450 to 600 mm.
- If characters cannot be enlarged enough, one shouid increase the line spacing to increase readability.
- A 5 pixel by 7 pixel matrix is the minimum for alphanumerics and upper case characters
- Text should have no more than three different fonts.
- Text should never be in all uppercase form, it is more difficult to read than normal upper- and lower-case text.
- No more than 2 variances in differences of points should be used, with a wide range of points between them. For example: 10 point and 14 point, not 10 point and 11 point.
- Because the Genesis system might evolve into foreign user markets it is important to allow at least two extra pixels for diacritics above and below the normal line of characters. (See diagram below) (Apple Computer 1987 [43])

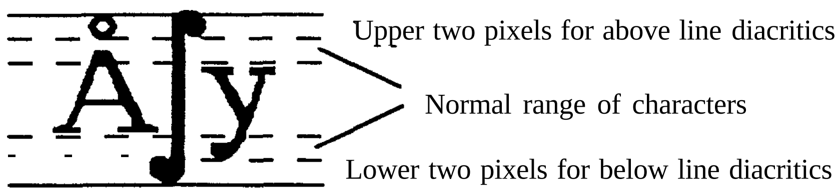

Figure A-2. Text sizing and positioning of diacritics

- Between Line spacing should be at least one pixel. However, when large amounts of text reading are necessary this should be increased to two pixels.
- Between Character spacing should also be at least one pixel according to Alderson and Dewolf in a 1984 study [44].

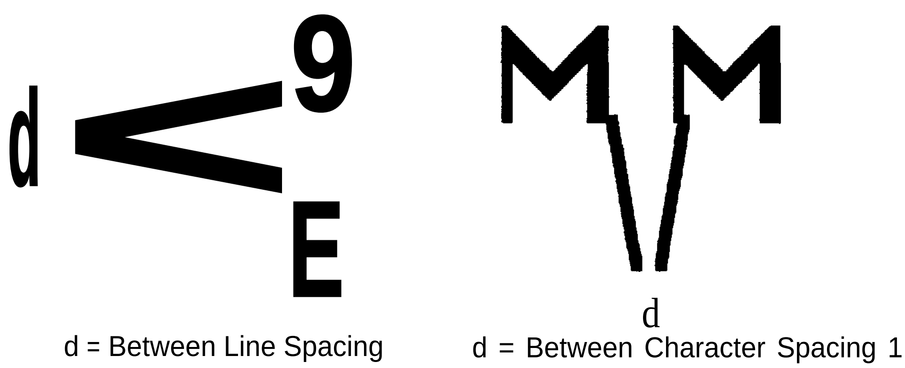

Figure A-3. illustration of font spacings.

- Text should range to the left for easiest readability, ranging to the right or centering leaves a jagged left edge which disrupts reading.

- Do not justify lines because this requires inconsistent spacing and hyphenation which is incompatible for low resolution systems.
- Line endings should coincide with grammatical conventions. Splitting words at the end of lines should be avoided.
- Paragraphs should be indicated by an additional line break not an indentation of the line according to Smith and Mosier in a 1986 study [44].

APPENDIX C

Additional Sources for Display And Message Design And Evaluation

ACM SIGGRAPH Symposium on User Interface Software (1st : 1988: Banff, Alta.) Proceedings of the ACM SIGGRAPH Symposium on User Interface Software : Baltimore, MD : Association for Computing Machinery.

ACM SIGGRAPH Symposium on User Interface Software and Technology (3rd : 1990 : Snowbird, Utah) Proceedings of the ACM SIGGRAPH Svmnosium on User Interface Software and Technology : New York, N.Y. : ACM Press.

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Application:	Microsoft Word
Document:	Microsoft Word - App C Title . . .
Date:	Monday, February 26,1996
Time:	8:54 AM
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Pages:	1

POSTSCRIPT
Software From Adobe

APPENDIX C

Additional Sources for Display and Message Design And Evaluation