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Human Factors Evaluation of the Truck Productivity Computer's™ Electroluminescent Display

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ABSTRACT

Electroluminescent (EL) displays are well known for their superior visual performance (brightness and contrast) and environmental performance (durability) characteristics. These characteristics contributed to Freightliner Corporation's selection of Planar Systems, Inc. to build a custom electroluminescent display that measures 80 pixels in height and 320 pixels in width for their Truck Productivity Computer. The Truck Productivity Computer is an open-platform information, communication, and integration system that fits in a standard (DIN 1) radio slot in a truck dashboard.

When compared to most conventional in-vehicle displays, the emissive EL technology offers increased brightness and contrast ratio. Considering these advantages and the type of information to be displayed, traditional human factors display guidelines, based primarily on other display types, were thought to be unsuitable for recommending character height for this display. It was hypothesized that a smaller font may be suitable for this display technology, while not sacrificing the required recognition times necessary for safe operation of the truck. Study 1, as described in this paper, was a human factors investigation to test whether character-size recommendations for conventional displays would apply to the EL display in this specific application. A soft-key label reading test and a subjective evaluation of font size was undertaken. It was found that subjects could read smaller text with an adequate level of accuracy and comfort in an appropriately short period of time. Study 2 was an in-truck validation of the findings of the first study.

INTRODUCTION

The clear legibility of a driver information display is necessary for efficient human-computer interaction and safe operation of the vehicle at highway speeds. The size of the font on the display is often an important factor in determining legibility. Many studies analyzing the effects of font size on legibility have been conducted. Preference and performance as a function of font size have been thoroughly calculated. As far back as 1886, Griffing and Franz compared 5-point type with 12-point type (Tinker, 1963). The 12-point was read 10% faster. They also found that legibility appeared to increase with type size up to 12-point. They suggested 10-point font as a lower limit. Tinker (1963) determined 11-point font to be the most legible in a study involving printed text. Both reader opinion and performance showed that 11-point font was the best, followed closely by 10- and 12-point fonts. Eye movements when reading 10- and 14-point fonts were examined. It was found that there was a significant reduction in efficiency of eye-movement patterns for the 14-point compared to the 10-point font. It must be remembered that an appropriate font type must be used.

In several studies it was found that reading from a video display terminal (VDT) decreased reading speed by 20-30% (Sanders and McCormick, 1993). This difference was related to image quality. The higher the resolution of the monitor, the less difference between reading from a VDT and from a hard copy. In an examination of minimum font size requirements for accurate legibility, Smith (1979) found that 12-15 minutes of arc angle was sufficient at "normal viewing distances" on electronic displays, but people preferred an angle of 23 minutes.

In 1988, ANSI/HFS released a set of standards for VDT workstations. The recommended minimum character height was 16 arcminutes and the preferred height was 20-22 arcminutes. For reading tasks which identification of individual characters was not time-critical, 10 arcminutes was the minimum. The minimum character height of 16 arcminutes was recommended by the Federal Highway Administration for static or noncritical elements in an Advanced Traveler Information System (ATIS) (USDOT, FHWA, Sept, 1998). For dynamic or critical elements, 20 arcminutes was the recommended minimum; titles and other key elements should be at least 30 arcminutes. It was observed that legibility begins to decrease with heights less than 18 minutes of arc. In 1989, the U.S. Department of Defense released a set of standards for military displays. For viewing

distances between 0.5 and 1.0 m, they recommended a minimum character height of 4.7 mm.

In the case of the Truck Productivity Computer, a size requirement was placed on the device so that it would be compatible with a standard radio slot and easily retrofit into existing trucks on an after-market basis. It was advantageous to use a smaller than recommended font size so that the driver would be able to see an adequate amount of information on the screen at one time while minimizing the need for abbreviations. The ANSI/HFS (Feb, 1988) guidelines state that when formatting advantages outweigh requirements of character heights recommended for rapid legibility and reading tasks, smaller characters may be used.

The development of higher contrast EL displays resistant to washout from sunlight has made them ideal for in-vehicle use. The other properties of the EL displays, such as excellent contrast, response time, large viewing angle, good image quality, and superior shock and vibration resistance have also made the technology attractive (Blass; USDOD, 1989). Recommended minimum contrast of display symbols is 3:1, with the preferred contrast being 7:1 (USDOT, FHWA, Sept, 1998). The contrast of the current Planar EL display is 150:1 (Planar, 2000). Zhu and Wu (1990) found that increased contrast and decreased background luminance improved performance, legibility and readability, and increased preference. It is believed that the superior contrast of the EL display will lead to increased legibility of smaller fonts. The medical industry has long recognized the visual performance benefits, using them in a variety of critical care applications over the last decade. Additionally, the decreased cost of EL technology has made it a viable option to other in-vehicle display technologies.

Bhise, Forbes and Farber (TRB, 1986) state that based on speed and travel distances of a moving vehicle, a single display glance greater than 2.5 seconds is inherently dangerous. The British Standards Institution Guidelines published in 1996 recommend that a single glance should be not more than 2 seconds so that it does not affect driving (Green, 1999). Battelle Guidelines suggest that the average glance time not exceed 1.6 seconds for a task to be considered safe for on-road use (Green, 1999).

One of the main design challenges of the Truck Productivity Computer was to safely present meaningful information to the driver in a limited display space (2.3 cm x 9.28 cm). With the superior contrast and brightness of the EL display, it was felt that the previously developed font-size recommendations may not apply directly to the current display. Therefore, two studies were carried out to determine adequate font size for “soft key” labels on the EL-equipped Truck Productivity Computer for on-road use. Study 1 was an initial study to determine optimal size of the soft-key labels in terms of readability and preference. Study 2 was an on-road validation study to test the adequacy of the soft-key label font size found from Study 1.

STUDY 1

METHOD

SUBJECTS – Twenty-nine volunteer subjects participated in Study 1. The subject group was comprised of 14 truck drivers (14 male) and 15 non-truck drivers (13 male, 2 female). The truck-driver subjects were located at a Portland-area truck stop and the non-truck driver subjects were Freightliner and DaimlerChrysler employees. Data from one truck-driver was not included in the soft-key performance portion. Subjects ranged in age from 23 to 59 years (mean age = 32).

APPARATUS – An EL display with five buttons, aligned in a row below the display, was used to simulate the actual Truck Productivity Computer system. A realistic depiction of routing directions was displayed. The display and associated text were driven by a specially designed desktop computer. A program was used that allowed the text to be displayed for a predetermined length of time (0.5, 1.0, and 1.5 seconds). These times were chosen based on glance times that research has shown to be consistent with safe operation of a moving vehicle. Once the predetermined time had elapsed, all displayed text would disappear. Additionally, the program allowed for presentation of several font sizes (6, 8, 9, 10, 12 point Tahoma). Reaction time data and accuracy of responses were recorded by an experimenter for later analysis. Viewing distance to the display approximated that of an actual Freightliner truck cab.

PROCEDURE – The soft key test consisted of presenting a realistic screen of a turn-by-turn navigation application with 5 soft-key labels. Subjects were presented with a “target” word and four “distractor” words, then prompted (via simple chime) to search the 5 soft-key labels for the target word. The subjects were instructed to press the key that corresponded to the target word.

Independent variables were:

1. font size (6, 8, 9, 10, 12 point Tahoma)
2. time on display (0.5s, 1.0s, 1.5s)

Dependent variables were:

1. subject response accuracy
2. user acceptance
3. user “ease of reading” rating
4. user “favorite” rating

DATA ANALYSIS OVERVIEW – Performance data were averaged for the 1.0- and 1.5-second conditions across all subjects. As mentioned above, these conditions represent acceptable glance duration for an in-vehicle display (Salvendy, 1997). The 0.5 second condition was also examined, but was found to be too short for the target word search task.

RESULTS

Figure 1 shows the number of subjects that correctly selected the target soft-key labels. The data indicate that 6-point font was clearly too small for subjects to accurately recognize. The data also show that there is little or no performance difference between the other font sizes.

Figure 2 shows the percentage of drivers who considered each font to be acceptable. Six-point font was rated considerably lower than the other font sizes. The data also show that 8- and 12-point font sizes tend to be rated slightly lower than the 9- and 10-point fonts. Post-test interviews revealed that the 8-point font was simply too small, and the 12-point font crowded the soft-key borders.

CONCLUSIONS

The results of Study 1 demonstrated that a 9- or 10-point font, displayed on the EL display, elicits accuracy of response and positive subjective opinion. Ten point font was chosen for an on-road test since it is slightly larger yet allows for an adequate amount of information to be displayed. Therefore, an on-road validation test of the 10-point font labels was conducted. It was expected that in the on-road study, factors such as vibration, changing traffic conditions, and numerous other dynamic conditions, would warrant the larger of the two sizes. It is felt that the excellent visual performance characteristics of the EL display contributed to the ease-of-readability of the smaller fonts.

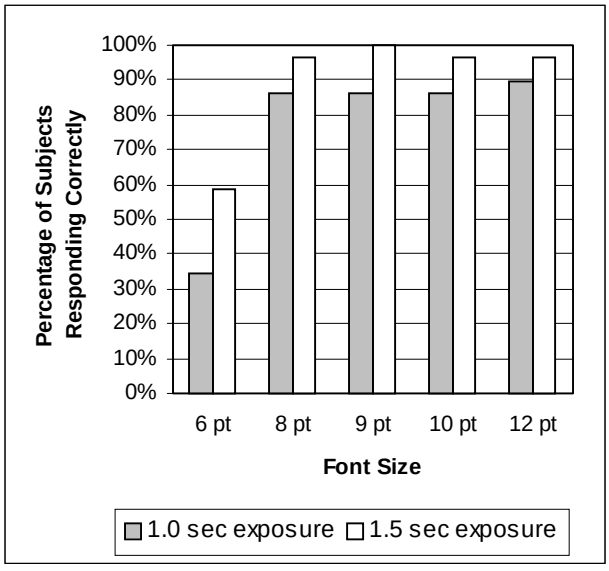

Figure 1. Percentage of Subjects Responding Correctly on Soft-Key Label Search Task with Different Size Font and Different "Glance" Times

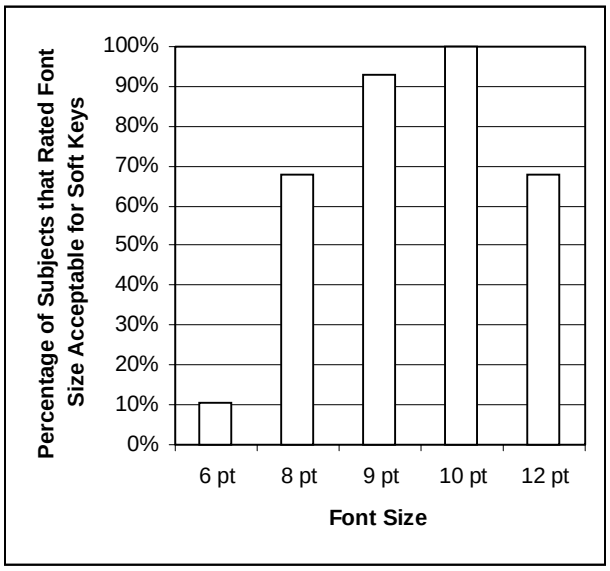

Figure 2. Soft-Key Acceptability Ratings

STUDY 2 - VALIDATION

Study 2 implemented the results of the first study into the heavy truck environment. This study was a validation of the results of the first study. The focus was on the readability of 10-point font (10.7 arcminutes) while driving.

METHOD

SUBJECTS – Eleven volunteer truck driver subjects (11 males), ranging in age from 29 to 60 years (mean age = 44), were used in this study. The subjects were employees of a Portland-area trucking company.

APPARATUS – The Truck Productivity Computer was installed in a Freightliner Argosy (class 8 commercial vehicle - no trailer) for on-road testing. Soft-keys with 10-point font labels (10.7 – 12.6 arcminutes, depending on driver height) were programmed to switch the system between preset radio stations and satellite radio music types (Figure 3). Video recording equipment (Figure 4) was used to record driver eye-movement information, driver interaction with the Truck Productivity Computer, and traffic density. The video was later viewed on a 20-inch color monitor for data reduction and analysis. A questionnaire and debriefing session were used to capture subjective driver feedback.

Figure 3. TruckPC Audio Screen Example

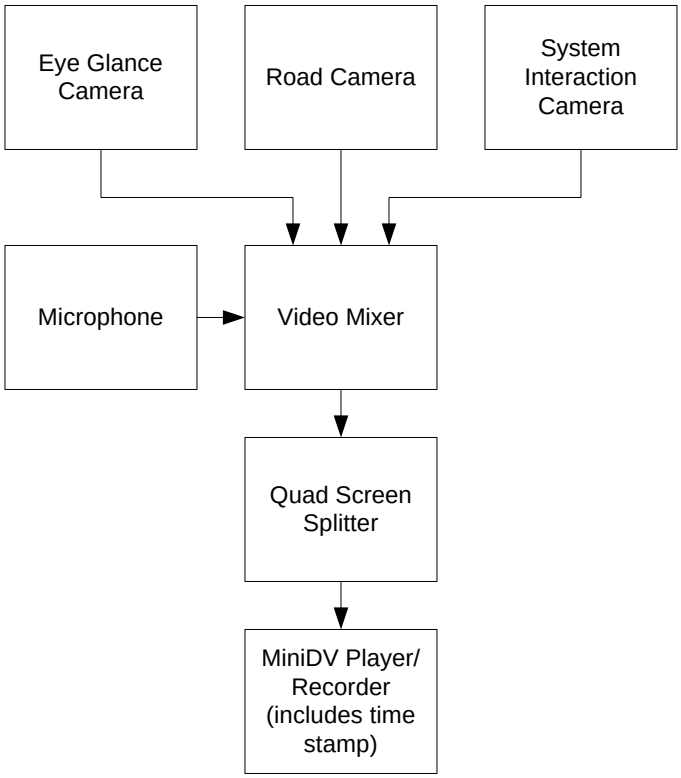

Figure 4. In-Truck Video Equipment

PROCEDURE – Drivers were asked to drive the equipped truck on a pre-determined course. It was emphasized to the drivers that they should drive as they normally would. During the test drive, two experimenters rode along with the participant. The drivers were prompted by an experimenter to search the 5 soft-key labels on the screen for a target word or FM frequency and then press the key that corresponded to the target word/frequency.

RESULTS – STUDY 2

Glance time and subjective driver opinion of the EL display were evaluated. During a debriefing session, participants rated the EL Display very positively. There was no glare and no sunlight-induced washout reported, or observed by the experimenters. This study was conducted under conditions ranging from overcast skies to bright sunlight.

Mean driver-head-down time (HDT) to search the 5 soft-key labels on the EL Display for a target word or FM frequency and then press the key that corresponded to the target word/frequency was 1.41 seconds. The 1.41 seconds consisted of a transition time to the display from the roadway of .226 seconds, a dwell time of .982 seconds, and a transition from the display to the roadway of .206 seconds. The mean number of glances per key press was 1.8. During the debriefing session, no subjective difficulties with this task were reported by the drivers.

SUBJECTIVE DRIVER EVALUATION – Following the data collection period, the test participants were asked several questions concerning the electroluminescent display. Eight out of ten participants stated that they preferred the EL display to “other displays that they are used to”. Statements such as “brightness is very good”, “very easy to read”, and “good even during bright day” were voiced.

CONCLUSIONS

It is important to note that during Study 2, the in-truck vibration was quite noticeable due to road conditions and the fact that no trailer was being pulled. Therefore, this was a desirable setting for “worst case” validation testing. The results of Study 2 validated the results of Study 1 in an actual driving environment. It can be concluded that with the Truck Productivity Computer’s EL Display font sizes smaller than are historically recommended can be used safely and with subjective comfort

Literature cited earlier stated that glance times longer than either 2.5 seconds, 2.0 seconds, or 1.6 seconds, depending on the study, were “inherently dangerous” and not recommended. The average glance time of 1.41 seconds calculated in this study demonstrated that reading radio labels with a font as small as 10.7 – 12.6 arcminutes is within these recommendations. Additionally, the number of glances per key press indicated that the drivers did
not have difficulty acquiring the “target” key (scanning, reading, and then pressing the associated key). Subjectively, the participants felt that that task was not difficult to accomplish. From all of this, we can see that the font was easy to read and the system was safe to operate, although the font was smaller than historically recommended and located in an environment with vibration and varying lighting conditions.

It is felt that the superior visual performance characteristics of EL Display contributed to the ease of readability. The EL Display offers excellent contrast and negligible background luminance, which has been found to result in faster recognition and response time. In addition, the display is not susceptible to washout from sunlight. Certainly, the EL Display received high subjective marks from the drivers during the debriefing sessions.

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