



Effects of e-map format and sub-windows on driving performance and glance behavior when using an in-vehicle navigation system

Ching-Torng Lin^a, Hsin-Chieh Wu^{b,*}, Ting-Yen Chien^a

^a Department of Information Management, Da-Yeh University, 168 University Road, Dacun, Changhua 51591, Taiwan, R.O.C.

^b Department of Industrial Engineering and Management, Chaoyang University of Technology, No. 168 Jifong E. Road, Wufong, Taichung County, 41349 Taiwan, R.O.C.

ARTICLE INFO

Article history:

Received 27 February 2009

Received in revised form

10 January 2010

Accepted 18 January 2010

Available online 11 February 2010

Keywords:

Display

Interface design

Driving performance

Visual demand

Map

ABSTRACT

An on-road driving experiment was conducted to investigate the effects of e-map format and sub-windows on driving performance and glance behavior of navigation system users. Twenty-eight participants navigated an urban route using the navigation display with 2D or 3D e-maps and either with or without sub-windows. Driver navigation errors and visual glance data were gathered during the trials. The analytical results demonstrate no significant difference in driving performance between the 2D and 3D e-map conditions. However, use of a 3D e-map was associated with significantly more frequent glance behavior than the 2D display. Furthermore, subjects using the navigation display with a sub-window made significantly fewer navigation errors (50% less) compared to those using the navigation display without a sub-window. This investigation suggests that performance improves when using sub-windows. Finally, this study discusses wider implications in the design and use of navigation displays.

Relevance to industry: We found that the e-map format is related to driver glance behavior when using an in-vehicle navigation display. The sub-window also provides substantial influence on driving performance and glance behavior. The results of our study will assist in designing in-vehicle navigation systems and improving the performance of navigation e-maps for path-finding tasks.

© 2010 Elsevier B.V. All rights reserved.

1. Introduction

The recent advances in global positioning systems (GPS) have resulted in automobile manufacturers producing intelligent transportation systems to assist drivers. These systems often include in-vehicle navigation systems. Navigation systems combine an electronic map (e-map) and permanent roadway signs to visually or aurally inform drivers of their current location and of relevant traffic information. These signs provide a technological solution to the problems associated with driver navigation in unfamiliar areas. While these systems benefit drivers by providing route guidance information and traffic status, drivers must adapt to simultaneously handling a larger visual load. Additionally, when receiving system information, drivers must divert their eyes from the road, a practice that seriously impacts driving safety. Distraction from the primary driving task is one of the most common causes of traffic accidents (Wierwille, 1995). Accordingly and optimally, the amount of information presented to drivers, including all distractions,

should not exceed their information processing capacity (Bendak and Al-Saleh, 2010). Previous studies have also reported that the increased visual demand associated with using a navigation system can negatively impact driving safety and performance (Ross and Burnett, 2001; Toshiaki et al., 2003; Williams and Helbig, 2006). Therefore, a major requirement in display-based navigation systems is the rapid and reliable transmission of easily understandable information (Baumann et al., 2004; Ma and Kaber, 2007).

Vision is the most important sense for the human, through which he or she receives 90% of the environmental information (Jung and Kee, 1996; Masih-Tehrani and Janabi-Sharifi, 2008). Thus, drivers prefer navigation systems in which route information is represented via a graphical visual display although auditory displays have received relatively low workload ratings (Liu, 2000; Streeter et al., 1985). Furthermore, under complex driving conditions, drivers may have greater difficulty in filtering and remembering useful information presented using an auditory display, largely owing to the problem of memory interference (Liu, 2000). To date, the moving e-map remains the primary medium for navigation and GPS applications (Sikanen et al., 2005). Further, it is unlikely that the visual e-map will ever be completely replaced by voice guidance. Therefore, incorporating a well-designed human-

* Corresponding author. Tel.: +886 4 2332 3000x4537; fax: +886 4 2374 2327.
E-mail address: hcwul@cyut.edu.tw (H.-C. Wu).

machine interface (HMI) into in-vehicle visual displays is an essential addition that will improve driving performance and reduce the duration of glances to the display.

The e-map presentation format has been refined from a two-dimensional (2D) to a three-dimensional (3D) format (Van Orden and Broyles, 2000). As the world exists in 3D, the 3D format more closely represents the 'real world', implying better human perception and performance. However, previous investigations have found that 3D displays are not markedly superior to 2D displays for air combat or air traffic control tasks (Tham and Wickens, 1993; Van Orden and Broyles, 2000). These studies largely focused on pilot and air traffic controller performance, and few studies have attempted to evaluate differences in driving performance when using the 2D or 3D formats. It is necessary to assess the influence of e-map format on driving performance and visual demand while using a navigation display.

Recently, multi-window interface technology has enabled navigation displays to simultaneously represent to both a main-window and a sub-window. The sub-window is generally designed to highlight information on turn direction (i.e., present the region of an upcoming intersection in large scale next to the main-window) when approaching an intersection. By combining a main-window with a sub-window, the navigation display provides noticeable and redundant route guidance for driver decision-making, possibly resulting in better navigational performance than a single-window display. However, an additional sub-window may increase the visual demands imposed on the user. The effect of sub-windows on driving performance remains poorly understood, since most navigation-related studies have only examined single-window displays (Liu, 2000; Streeter et al., 1985; Sikanen et al., 2005; Van Orden and Broyles, 2000). Further, the interaction between sub-windows and driver distraction remains unclear.

Many countries have not yet implemented regulations to ensure safety in the use of in-vehicle navigation systems. It is important to understand which navigation display representation formats can safely and efficiently assist drivers, particularly when navigating in a compact city with numerous intersections. To obtain more reliable evidence regarding the effects of e-map format and sub-windows, we performed a controlled on-road driving experiment, as opposed to the more common simulated driving trial in a virtual environment (Eoh et al., 2005; Godwin et al., 2008; Godwin and Eger, 2009). This study attempts to investigate the extent to which drivers benefited from the inclusion of 3D representations and sub-windows in a navigation display. This study used two key benchmark comparisons: (1) driving performance and glance behavior with and without a sub-window, and (2) driving performance and glance behavior using a 2D e-map format compared to performance and glance behavior using a 3D format for navigation purposes.

2. Methods

2.1. Subjects

In the first stage, 35 young male adults with mean age of 26.4 (± 3.6) years were recruited as candidate subjects. All candidate subjects satisfied the following criteria: clean driving license; regular drivers for at least the previous three years; unfamiliar with the study area; no previous use of an in-vehicle navigation system; normal (20/20) or corrected to normal visual acuity and normal color vision. Previous studies have shown that navigation ability potentially influences driving performance, driving behavior and/or information preference (Allerton, 2000; Burns, 1998; Streeter and Vitello, 1986). In order to compensate for differences in the

navigation ability of the test subjects, candidate subjects were tested for map-reading ability using an e-map displayed on a computer screen. Specifically, the 35 candidate subjects were asked to identify a feasible path to a destination from a given starting position. Candidate subjects were instructed to record the street names and turn information for the identified path as quickly as possible. Task completion time and accuracy were combined as a total score for the map-reading test. Ultimately, 28 participants passed the baseline of the map-reading test with similar performance scores were recruited as formal subjects. The aims of this study were explained in detail to all participants before the driving trial. Upon completion of the on-road driving trial, subjects were compensated for their participation.

2.2. Apparatus

The on-road driving experiment was performed in a mid-size automobile (Ford Telstart 1800). Two PC cameras (Logitech Quick-Cam Messenger) were used to monitor driver responses and road conditions. Each PC camera captured 30 frames per second and was connected to a notebook computer for data processing. The MIO Moov series of navigation systems with the MioMap software were used to provide the study participants with moving e-maps and visual turn instructions. The navigation system is capable of presenting either the 2D-'plan' view (vertical top-down route view) or the 3D-perspective e-map. In addition to the e-map, the system displayed a moving direction arrow, distance to the next turn, the name of the current road and the name of the road onto which the participant would be turning. The application software was run on the Win CE.Net 4.2 platform using a Samsung 400 MHz processor and 64 MB RAM. The navigation system incorporated a 3.5-in. diagonal TFT-LCD screen with a resolution of 320 horizontal pixels by 240 vertical pixels.

2.3. Experimental design

2.3.1. Independent variables

This work assesses two independent variables: e-map format and presence of a sub-window. The e-map format was a between-subject factor and included either 2D or 3D e-maps to represent the navigation route on the display. The presence or absence of a sub-window was also a between-subject factor with two levels, no sub-window or one sub-window. Four experimental conditions (2×2) were generated from the combination of the e-map format and sub-window variables. The test navigation system was set to display each experimental condition, as illustrated in Fig. 1. Twenty-eight subjects were carefully divided into four equal-sized groups, with age, map-reading ability and years as a licensed driver balanced between the groups. Each group was then assigned to one of the four experimental conditions.

2.3.2. Dependent variables

Dependent variables related to driving performance and visual glance behavior were captured. All navigation errors were recorded by the observer accompanying each subject during the driving trial. Navigation errors were defined as situations where a subject took a wrong turn or missed a turn while following the directional advice of a navigation system during the trial. This study focused on the possibility that the different experimental conditions influenced the number and magnitude of subject navigation errors during the driving trials. Generally, it is agreed that the number of navigation errors provides a good measure of driving performance when using a navigation system (Burns, 1998; Liu, 2000; Ma and Kaber, 2007; May et al., 2005).

Download English Version:

<https://daneshyari.com/en/article/1096437>

Download Persian Version:

<https://daneshyari.com/article/1096437>

[Daneshyari.com](https://daneshyari.com)