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The Impact of GPS Interface Design on Driving and Distraction

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This study empirically examined the effects of keyboard type in a GPS system on driver distraction. Fifty-two undergraduate students were recruited to drive in a simulated environment while using either a QWERTY or ABCD keyboard embedded in a GPS interface. Driving errors, as well as bio-behavioral assessments, eye fixation durations, and EEG (Electroencephalography) theta frequency level were collected to determine the level of distraction and driving performance of participants. Significant differences in driving and distraction measures were found between driving with and without GPS data entry. Despite greater pre-existing participant skill in using two-handed QWERTY keyboards, no differences were found between the two keyboard types when used one-handed while driving. Implications for driver safety, in-vehicle systems design, and distraction research are discussed.

INTRODUCTION

Driver distraction has attracted great attention not only within research, but also transportation, manufacturing, legislation and public policy. In 2008, government transportation officials reported nearly 6,000 fatalities and half a million injuries in accidents determined to be caused by driver distraction (NHTSA, 2009). Thirty nine states and the District of Columbia currently have legislation either banning or limiting the use of cellular phones while driving (IIHS, 2011). However, cell phones are hardly the sole causes of driver distraction, and other telematics devices are also a cause of driver distraction (Lee, 2007).

Global Positioning System (GPS) units have been a top selling consumer electronic product since 2008, with 17.4 million units purchased in 2009 alone (Saltzman, 2009). In-vehicle GPS units have been found to decrease driving performance and increase glances away from the road (Jensen, Skov & Thiruravichandran, 2010). Sheridan (2004) defines driver distraction as “a process or condition that draws away driver attention, thereby disturbing driving control” (p. 588). Tasks such as address and POI (Point of Interest) lookup certainly require driver attention. What is worse, they, like driving, are primarily visual in nature. According to Wickens’ (2002; 2008) multiple resource model, two tasks that use the same modality cannot both be performed effectively, and this is because there are different resources for each modality; thus, when more than one task is present for that modality, the resources will have to be shared.

Entering data by keyboard is frequent among GPS tasks that may be a cause for concern (Tsimhoni, Smith & Green, 2004). Keyboard interfaces across all types of devices, regardless of display size and degree of haptic feedback, largely default to the QWERTY layout. Designers assume users will already be familiar with QWERTY, and therefore enjoy some level of skill transfer to this popular format (Green et al, 2004, Isokoski & Raisamo, 2000). However, users are generally skilled in computer keyboard use, and little research exists on skill transfer from two-handed to one-handed keyboards, much less in the context of a high-load situation like driving. Even assuming that users are more comfortable with a familiar keyboard, there has not been sufficient research to connect this asserted comfort level with less distracted driving.

Previous research showed an adverse impact of GPS systems on driver distraction shown in previous research (Jensen, Skov & Thiruravichandran, 2010). The current research sought not only to empirically examine this effect, but to also explore the relative distraction contributions of two diverse keyboard layouts: QWERTY and ABCD, and its effect on driver performance and usability. It was expected that the lack of familiarity participants had with the ABCD layout would lead to diminished preference and usability ratings for that layout, as well as poorer driving performance in contrast to the already familiar QWERTY layout.

METHODS

Participants

Fifty-two undergraduate students (21 males and 31 females) between the ages of 18 and 22 participated in this study. They were recruited through the SONA system at the University of Central Florida, and were given course credit as compensation. The treatment of the participants was in accordance with the ethical standards of the APA.

Materials

A typing skill test and a number of questionnaires were administered to assess various state and trait attributes of the participants, as well as to assess their perceptions of their own performance with the aforementioned devices. Pre-driving questionnaires included a driving behaviors questionnaire, a Post-Study System Usability Questionnaire, and a number of items to assess prior experience with navigational devices and keyboard layouts. After driving, participants completed a number of 7-point Likert scale items regarding GPS usage and preference.

Participants completed driving tasks in a GE iSim PatrolSim fixed platform driving simulator. This simulator consists of three screens in front of the participant, giving them a 150-degree view of the virtual roadway ahead. The simulated environment ranged from urban to rural. The iSim had the ability to archive recorded driving data for later analysis.

The Omitech GPS used Distinator 8 maps and ran Windows CE.

Eye tracking data was recorded using a Seeing Machines eye tracker system, and analyzed using faceLAB 5 (Seeing Machines, 2011). The eye tracker system consisted of two small cameras mounted to the dash of the vehicle. The faceLAB software allowed for the construction of a virtual "world model." This included the dimensions of the screens from the GE iSim simulator and the positioning of the GPS within it, as well as the position and relative distance of the participant in relation to these objects. This allowed detailed assessment of gaze time for both the screens displaying the driving environment and the GPS unit.

EEG data was recorded with a BrainMaster Atlantis EEG amplifier. The data was recorded from the chosen input channels in real-time, and quantitatively measured variations in the selected frequency bands.

Design and Procedure

We utilized a 3x2 mixed Factorial design evaluating driving before, during, and after a GPS manipulation. Within the 'during' condition keyboard type (QWERTY or ABCD) was further manipulated.

Upon arrival to the lab, participants were randomly assigned to a keyboard type to use in the study (QWERTY or ABCD), given a consent form, and an opportunity to ask questions before beginning the study. In addition to standard opt-out procedures included in the informed consent, participants were also verbally informed of the simulation sickness phenomenon and advised to alert the researchers to halt the simulation at any point if they experienced troubling symptoms.

Participants were first given a two-minute typing test to gauge their skill on a full QWERTY keyboard at a computer desk. Next, they completed a Driving Behavior Survey, and a questionnaire about their prior experience using GPS devices and both keyboard layouts. They were then given an opportunity to practice navigating the menus and typing a sample address and a sample "point of interest" (POI) into the GPS on their assigned keyboard type. Following this practice period, participants were asked to rate the usability of the GPS interface to which they were assigned.

Following this initial round of practice and questionnaires, participants were seated in the simulator so that the eye tracking and EEG equipment could be calibrated for that person's height and seat position. Micro voltage threshold on the BrainMaster was changed to account for eye blinking. The sampling rate of the BrainMaster was set to 256 samples per second. EEG data files recorded the same frequency band settings for all participants. These bands consisted of Delta (1.0-3.0 Hz), Theta (4-7 Hz), Alpha (8-12 Hz), Lobeta (12-15 Hz), Beta (15-20 Hz), Hibeta (20-30 Hz), and Gamma (38-42 Hz). After the participant's file was set up, he or she was asked to sit still while a researcher placed one electrode on the participants head (channel Fz), one on the right ear as a reference (channel A2), and one on the left ear as a ground (channel A1). After the electrode connections were correctly positioned and fixed, the participant was asked to relax and sit still while a one-minute baseline EEG reading was recorded.

Participants were given an opportunity to practice driving on the simulator for two minutes. After the practice period, the driving tasks began. Each participant drove in three separate sessions through the simulation environment, following road signs with black directional arrows on a white background. Each session of driving lasted for a duration of four minutes. All sessions were identical in the placement of the participant's vehicle in the environment and had the same route marked for participants to follow. During the second of these three sessions, the participant was instructed to enter four pre-determined locations into the GPS while they drove. These locations were posted on an index card below the GPS, and consisted of two street addresses and two POIs. This address entry task took the duration of the drive, and no participant finished the task before completing the drive.

At the end of the each session, a recording of the drive was saved for later analysis and coding of driving errors and speed. Errors recorded consisted of lane deviations, crossing the median, leaving the roadway, collisions, and disobeying traffic lights/signs. The recordings were also used to track speed throughout each session.

Following the third and final session, each participant was detached from the EEG electrodes and taken back into the questionnaire area. At this point, they completed the GPS usage and preference questionnaire. They were also asked to complete a demographic form before being debriefed and released.

RESULTS

A mixed design ANOVA was used to examine effects of keyboard type (QWERTY and ABCD) on driving performance. In all three measures (driving data, EEG, and eye-tracking), main effects were found for driving sessions *(F* (2,88) = 46.480, *p* = .000; *F*(2, 84) = 25.987, *p* = .000; *F*(2, 90) = 228.942, *p* = .000, respectively) with the highest level of distraction in the second session (*M* = 4.80; *M* = 5.37; *M* = 0.411, respectively). See Figures 1, 2, and 3. Despite high participant proficiency with QWERTY keyboards (*M* = 6.769) and low proficiency in ABCD (*M* = 1.269) keyboards (*t*(51) = -21.787*, p* = .000), no significant differences were found due to keyboard layout in any of the three measures (*F*(2, 88) = 0.961, *p* = .387; *F*(2, 84) = 0.312, *p* = .733; *F*(2, 90) = 0.021, *p* = .692, respectively). Participants who used the ABCD keyboard did report a higher perceived level of difficulty (*t*(50) = -1.621, *p* = .001), as well as a lower level of usability (*t*(50) = -1.662, *p* = .004), but this difference was not reflected in actual driving performance, EEG, or eye tracker results between groups.

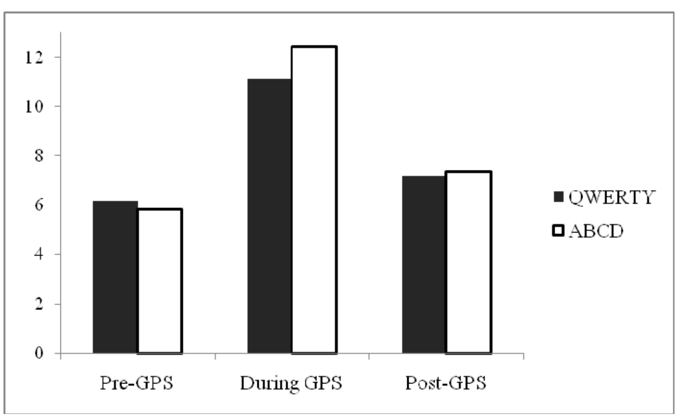

Figure 1. Total driving errors between sessions in QWERTY and ABCD groups

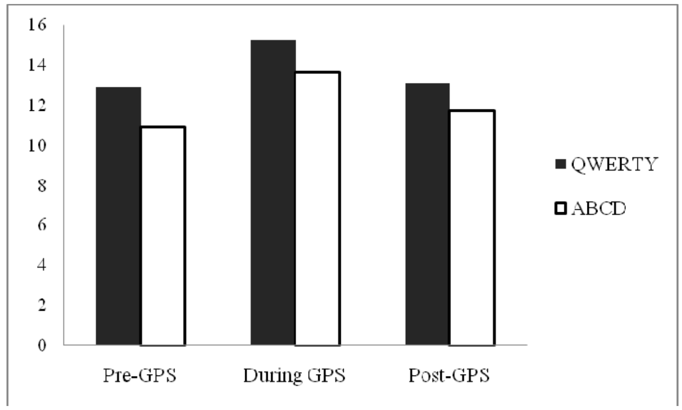

Figure 2. EEG Theta waves between sessions of QWERTY and ABCD groups.

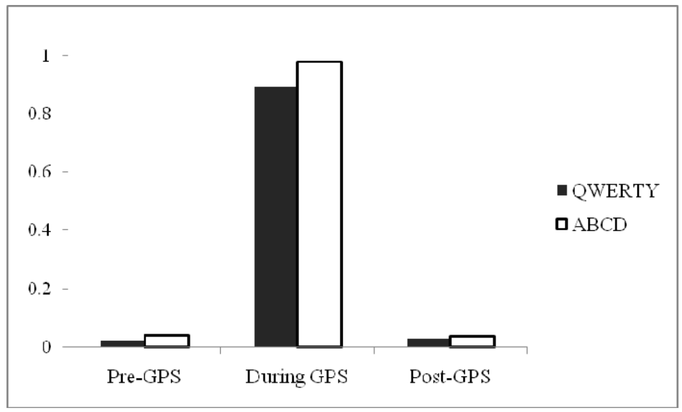

Figure 3. Eye fixation durations on GPS between sessions of QWERTY and ABCD groups.

DISCUSSION

The present findings support prior work showing that address entry in GPS systems has adverse effects on driving performance (Jensen, Skov & Thiruravichandran, 2010; Tsimhoni, Smith & Green, 2004). Qualitative driving performance was significantly worse when participants engaged in a task than when they drove without any distraction. EEG results showed a significantly increased theta wave when the GPS was used. Theta wave increases have been shown to be a useful measure of concurrent level of distraction (Lin et al., 2008; Mouloua et al., 2010). Eye tracker results further supported the deleterious effects of the GPS use manipulations. Fixations on the GPS were significantly higher in the second session than in the other two sessions. Taken together, these data support a decrease of attention during the dual-task session, leading to a decrease in performance. These findings are consistent with existing driving research where performance was impaired during GPS address entry (Tsimhoni, Smith & Green, 2004), as well as research showing increases in glances away from the roadway, (Jensen, Skov & Thiruravichandran, 2010) and other in-vehicle device based driving distraction research (Mouloua, Rinalducci, Hancock, & Aty, 2001).

The present findings clearly indicate that QWERTY and ABCD keyboards are equally distracting. This calls into question current QWERTY dominance in in-vehicle keyboards. As mentioned before, designers assume users will prefer the familiar QWERTY layout, and enjoy some level of skill transfer to this popular format (Green et al, 2004, Isokoski & Raisamo, 2000). The first assumption is in part supported by our findings; in our pre-driving usability assessment participants rated QWERTY significantly higher than ABCD. In the post-driving questionnaire, they additionally rated QWERTY as significantly easier to use. However, in that same post-driving questionnaire no significant preference for either keyboard was expressed. This may be an astute observation on the part of our subjects; QWERTY provided no significant relief from the impairment of GPS address entry; QWERTY and ABCD keyboard users were not significantly different in driving performance, EEG based attention, or glances away from the road. It is especially surprising that, even in eye-tracking measurement, no significant differences were found even though ABCD keyboards were significantly less familiar to participants. Taken together, these data suggest that the only benefits of QWERTY were subjective. Although participants rated the QWERTY to have a higher level of usability, this was not reflected in their driving performance. Participants of both groups were similar in all three measures when using the GPS while driving.

It now seems likely that use of a familiar two-handed computer keyboard layout does not result in skill transfer and reduced workload when using a one-handed keyboard while driving. Interesting new possibilities likewise emerge. If users are not tapping their skill at manipulating the QWERTY layout, what is their strategy? One possibility lies in the switch from parallel to serial search strategies that can occur in the midst of a demanding, dual task situation, especially when the temporal constraints of the situation are not obvious (Pashler, 1994). In such a situation, participants might resort to serial search regardless of the keyboard type in question or their prior two-handed experience.

From a more pragmatic angle, the inability of familiar QWERTY to mitigate data entry driven driving detriment represents an opportunity: if not QWERTY, then what? Although the best policy is certainly to abstain from data entry on the road, in some situations it cannot be or simply is not avoided. Might another keyboard layout provide a significantly better interface for a dual task addled mind? Looking at the previous supposition, that serial search is responsible for the lack of skill transfer seen, it could be argued that a layout with the most-used letters at the left, where visual scans begin, might be superior. Regardless, the development of a keyboard that mitigated driver distraction would be a benefit indeed.

These findings suggest that user preference for QWERTY keyboards is not necessarily representative of a benefit to the user in terms of driving performance. Neither keyboard is “safer” than the other, as QWERTY and ABCD keyboards were not significantly different in their impact on driving performance. The findings also call into question the belief that use of a familiar two-handed keyboard layout such as QWERTY might result in skill transfer and reduced workload for users. Perhaps designers of alternative keyboards should attempt to extrapolate search strategies that drivers apply when entering addresses while driving, and design accordingly. Further research into the phenomenon of one-handed in-vehicle keyboarding, and into the potential dangers of in-vehicle telematic devices that require it, is needed.

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