In-Vehicle Assistive Technology (IVAT) for Drivers Who Have Survived a Traumatic Brain Injury

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ABSTRACT

IVAT (in-vehicle assistive technology) is an in-dash interface borne out from a collaborative effort between the Shepherd Center assistive technology team, the Georgia Tech Sonification Laboratory, and Centrafuse™. The aim of this technology is to increase driver safety by taking individual cognitive abilities and limitations into account. While the potential applications of IVAT are widespread, the initial population of interest for the current research is survivors of a traumatic brain injury (TBI). TBI can cause a variety of impairments that limit driving ability. IVAT is aimed at enabling the individual to overcome these limitations in order to regain some independence by driving after injury.

Categories and Subject Descriptors

J.4 [**Computer Applications**]: Social and Behavioral Sciences – *Psychology.*

General Terms

Performance, Design, Human Factors

Keywords

Driving, Cognitive Limitations, TBI, Assistive Technology, Human Factors

1. INTRODUCTION

Millions of people incur, and then strive to recover from, traumatic brain injuries (TBI) each year. Following extensive rehabilitation, they are often able to reintegrate into daily life. The ability to drive a car unsupervised is often a critical factor in regaining independence. Unfortunately, many TBI survivors (and indeed people with various disabilities) have residual perceptual, cognitive, motor, or affect-control deficits that impact their ability to drive, among other activities. To assist people who have had TBI be better, more independent drivers, we have developed an in-vehicle assistive technology (IVAT). The system is, in fact, a framework for developing a range of assistive applications, each one tuned to the particular needs of the individual driver. In the current research, an in-vehicle PC is utilized with Centrafuse Application Integration Framework software that merges connected car technology and IVAT in a multimodal in-dash touch screen interface (see Figure 1). IVAT utilizes driver interaction and multimodal positive reinforcement to improve and sustain behaviors known to increase driver safety.

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Figure 1. IVAT in-dash display.

2. TRAUMATIC BRAIN INJURY

2.1 TBI Classification

The level and type of cognitive limitations resulting from TBI depend on the injury details: severity, mechanism, and location. The most common causes of TBI include violence, transportation accidents, construction mishaps, and sports injuries [6]. Brain concussion, cortical contusions, intracranial hemorrhage, and axonal shear injury may occur with both open and closed head injuries. Classification is generally made using observational ratings such as the Glasgow Outcome Scale (GOS) or the Disability Rating Scale (DRS) [3]. These provide the criteria for TBI classification as mild, moderate, or severe. Classification into these categories allows determination of appropriate treatment and early identification of potential sequelae [6]. Even after rehabilitation, permanent cognitive impairment may or may not preclude an individual from becoming a safe driver [7]. Correct identification of unsafe drivers is of critical import for both the TBI survivor and his or her potential fellow drivers.

2.2 Driving After TBI

Driving after TBI has been identified as a critical component of achieving autonomy and reintegration into the mainstream community [2]. Despite great potential risks, the percentage of individuals who return to driving after TBI is believed to be as high as 60% [3] of the 2 million new cases in the U.S. each year [4]. Less than half of these (37%) ever receive professional driving evaluation [3]. Cognitive, behavioral, and physical sequelae commonly associated with TBI that have been shown to have negative effects on safe driving include: information processing speed, psychomotor speed, visuospatial ability, and executive function including meta-awareness of individual self limitations [7][1]. Assessment of these key symptoms has been shown to validly predict safe-driving ability after brain injury [7]. Successful rehabilitation must address these population-specific needs. Training that focuses on visual scanning, spatial perception, attention focusing skills, and problem solving is believed to significantly improve driver awareness of shortcomings and driving abilities (anosognosia) [7] Similarly, the

Shepherd Center rehabilitation hospital's driving evaluators report mirror scanning, space monitoring, and environmental awareness as the key skills that need to be trained in order to improve clients' defensive driving abilities [1]. For these reasons, the current iteration of IVAT focuses on these three driving skills.

2.3 A Shepherd Center Case Study

One challenge for driving evaluators stems from the tendency of TBI clients to be better able to remain focused on the driving task in the presence of the evaluator than when driving solo. As part of a limited self-awareness of individual deficits, some TBI survivors have a propensity to forget that they are driving. This can be observed by a 'glazed over' look and the onset of defensive driving practice neglect [1]. While working with one such individual exhibiting an attention deficit, Shepherd Center evaluators noted that a lack of stimulation for 6-7 minutes resulted in swerving, disregard for traffic signals, and poor space management. This individual was capable of passing evaluation, but would then experience problems once returning home to a normal driving routine. The individual accumulated traffic violations and was in jeopardy of losing driving licensure.

In order to replicate the experience of driving with an evaluator, the Shepherd Center team designed a device they called the Electronic Driving Coach (EDC). The EDC is a three-button box that rests on the driver console. Each of the buttons is labeled to match the three tasks this individual most needed to remember to practice in order to be a safe driver: mirror scanning, speed maintenance, and space monitoring. Every time the individual noticed himself practicing one of these tasks, he was to push the corresponding button. The EDC would then give the driver auditory positive feedback. For instance, if the driver noticed that he was checking his speed and pushed the corresponding 'speed' button, the EDC might display, "Great job checking your speed! It's easy to accidentally drive faster than the posted limit." After a 3, 6, and 12-month re-evaluation, the individual's driving skills have been rehabilitated to a much safer level as evidenced by continued evaluations and the discontinuation of traffic violations.

3. IVAT

3.1 IVAT Design

The early success of the Shepherd Center's EDC with this initial individual and a handful of clients afterward motivated the current research project. Our goals were to: ***1) Understand the variety and extent of disabilities affecting individuals with TBI***. The direction and methods of the design were informed by qualitative research. We conducted interviews with several physical therapists having at least two years of clinical experience with TBI clients. These interviews served to support the literature findings and provide design guidelines necessary for an effective assistive technology. ***2) Create design guidelines to support the cognitive (dis)abilities of potential users.*** The guidelines correlated data from the interviews with the framework established from our literature review. This further clarified the most common disabilities among individuals with TBI who still retain driving capabilities. Disabilities found to be common among these individuals highlighted the most relevant needs and critical elements necessary for an effective design. ***3) Test the design's benefits on potential users of IVAT.*** Focus groups consisting of therapists and TBI clients were shown example driving situation videos. Feedback was collected on the effectiveness of an assistive technology and modality preference for the design concepts. ***4) Design a prototype based on client feedback***. A demonstration video simulated the IVAT system in ecological driving conditions, with actual auditory and visual interfaces included. As part of the design prototype, a taxonomy of specific occurrences and notifications from the system to the driver were based on research and standards. This served as the criteria for the creation of the system. ***5) Validate the design with the users and therapists.*** A final focus group of therapists and cognitively impaired potential users saw the design prototypes and assessed the validity of the design. Focus group feedback is informing future developments and modules for IVAT.

3.2 IVAT Application Framework

The limitations of the physical button box are obvious. The potential (and need) for a more flexible software-based IVAT system became clear through our focus group efforts. Thus, using the research-informed prototype design, we created IVAT as an assistive technology plug-in architecture within Centrafuse. We also built the first AT plug-in module to mimic the functionality of the original EDC button box, but utilizing touch-screen software. In addition to the functionality of the original button box, IVAT features an in-dash touch screen display rather than the clunky box, is customizable for individuals with varying levels and types of cognitive and perceptual limitations, can log driving performance information, and merges with additional in-vehicle infotainment systems. A wide range of novel plug-ins may now be created and then deployed on a driver-by-driver basis depending on his or her particular diagnoses. The data logging capabilities inherent in the IVAT framework are also useful for evaluators who can track objective performance measures over time (e.g., between rehabilitative sessions). Currently, IVAT is fully functional as a Centrafuse application and we will now begin running systematic empirical evaluations both in a simulator and in on-road vehicles in the near future. The initial population of interest has been TBI survivors, but in-vehicle assistive technology has potential benefits for other high-risk populations such as older adults and new drivers.

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