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Intelligent speed adaptation as an assistive device for drivers with acquired brain injury: A single-case field experiment

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ABSTRACT

Intelligent speed adaptation (ISA) was tested as an assistive device for drivers with an acquired brain injury (ABI). The study was part of the "Pay as You Speed" project (PAYS) and used the same equipment and technology as the main study (Lahrmann et al., in press-a, in press-b). Two drivers with ABI were recruited as subjects and had ISA equipment installed in their private vehicle. Their speed was logged with ISA equipment for a total of 30 weeks of which 12 weeks were with an active ISA user interface (6 weeks = Baseline 1; 12 weeks = ISA period; 12 weeks = Baseline 2). The subjects participated in two semi-structured interviews concerning their strategies for driving with ABI and for driving with ISA. Furthermore, they gave consent to have data from their clinical journals and be a part of the study. The two subjects did not report any instances of being distracted or confused by ISA, and in general they described driving with ISA as relaxed. ISA reduced the percentage of the total distance that was driven with a speed above the speed limit (PDA), but the subjects relapsed to their previous PDA level in Baseline 2. This suggests that ISA is more suited as a permanent assistive device (i.e. cognitive prosthesis) than as a temporary training device. As ABI is associated with a multitude of cognitive deficits, we developed a conceptual framework, which focused on the cognitive parameters that have been shown to relate to speeding behaviour, namely "intention to speed" and "inattention to speeding". The subjects' combined status on the two independent parameters made up their "speeding profile". A comparison of the speeding profiles and the speed logs indicated that ISA in the present study was more efficient in reducing inattention to speeding than affecting intention to speed. This finding suggests that ISA might be more suited for some neuropsychological profiles than for others, and that customisation of ISA for different neuropsychological profiles may be required. However, further studies with more subjects are needed in order to be conclusive on these issues.

1. Introduction

Intelligent speed adaptation (ISA) has been studied extensively in the past two decades. The first line of research within the field tended to focus on technologies that aimed to reduce the subjects' mean speed when driving with active ISA, and most of these technologies were successful in doing this (reviews: Regan et al., 2006; Warner, 2006). A second line of research within the ISA field is now appearing, dealing with the more user-centred issues. ISA problems relating to the user, e.g. poor acceptance of ISA equipment and difficulties in recruiting subjects for ISA-studies, have proven difficult to be solved. From this, it has been concluded that the drivers who need ISA the most may not be willing to use it voluntarily (Lahrmann et al., in press-a, in press-b; Jamson, 2006).

The idea to test ISA with drivers having acquired brain injury (ABI), which is a narrower inclusion criterion than seen in other studies, arose in the wake of the above conclusion. Given that ISA has a potential for reducing (a) the cognitive workload of driving by demanding less attention for monitoring speedometer and speed limit signs, and (b) decision making processes associated with choosing an appropriate speed (if the driver complies with the system), then drivers with ABI compose a group of users who might not only need the equipment, but also might voluntarily want it as an assistive device that facilitates post-injury driving. The prevalence of persons with ABI is growing due to medical advances leading to improved survival rates. Since the ability to drive after an ABI has been associated with high measures of autonomy and quality of daily life (Fisk et al., 1998; Edwards et al., 2006), it seems a new and promising field of implementation to use ISA as an assistive device. However, the inherent problem of most assistive devices is

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Table 1
Dichotomized terms parallel to"intention to speed" and "inattention to speeding.".

Intention to speed	or	Inattention to speeding
Violation	or	Error
Poor selection of target speed	or	Poor adjustment of speed to target speed
Social context contributors to speeding	or	Individual cognitive contributors to speeding
Attitude and motivation problems	or	Information processing problems
Conscious speeding	or	Unconscious speeding
Deliberate speeding	or	Involuntary speeding

whether it is independent of the processes that it is supposed to compensate for. If one makes an assistive device to support memory function, it is important that the use of the device is intuitive and does not itself require memory. In the same way it is important that the ISA equipment does not attract more attention than is freed by its functionality. Clarifying whether ISA in some situations becomes a distraction will be our first focus in the present study.

Our second focus describes the subjects' speeding profile and its interaction with ISA. As ABI is associated with a multitude of cognitive deficits, we preferred to have a conceptual framework as a basis for the speeding profiles, which only focused on the cognitive areas shown to be related to speeding behaviour. Literature in the field displayed a tendency to divide the causes of speeding into two main categories, which we in this cognitive-oriented context will term "intention to speed" and "inattention to speeding". Some of the related terms are listed in Table 1 (Reason et al., 1990; Aberg and Warner, 2008).

The categories are often presented as dichotomised, i.e. mutually exclusive (e.g. as in the title "Speeding – deliberate violation or involuntary mistake?" (Aberg and Warner, 2008)). In our work we will use the idea of these two categories as being the main contributors to speeding behaviour, but rather than regarding "intention to speed" and "inattention to speeding" as dichotomised categories, we consider them to be independent parameters, i.e. the presence of one of the two does neither exclude nor include the presence of the other. If tools were constructed specifically for measuring "intention to speed" and "inattention to speeding", it would be possible to display a driver's "personal speeding profile" as a point in a coordinate system with the parameters represented on the *x*- and *y*-axis, respectively. A simplified version of such a coordinate system is the cross-tab presented in Table 2. The four speeding profiles in Table 2 correspond to the four extreme corners of the coordinate system.

One of the advantages of the independent parameters approach is that all causes of speeding can be addressed in cases with more than one contributing parameter (speeding profiles which approach profile 4 in Table 2). Seeing the two as independent becomes especially meaningful when working with drivers with ABI; although both "intention to speed" and "inattention to speeding" are normal findings in all populations, the parameters can also be sequelae of ABI (reduced executive functions/reduced attention). Lesion studies have found double dissociations between these cognitive areas, implying that it is possible to have reductions in either of the two cognitive areas independently, or in both, depending on the location of the injury.

The present study, which is a sub-study to the project "Pay as You Speed" (PAYS) in North Jutland (Lahrmann et al., in press-a, in press-b), did not have the possibility to recruit subjects by screening medical journals, therefore, recruitment took place in cooperation with a local brain injury rehabilitation centre, which resulted in recruitment of only two subjects. Obviously, with only two subjects it is not possible to perform a complete test of the framework described above; however, we decided to go forward with a small study using a mix of quantitative data (single case ABA research design) and qualitative data (semi-structured interview) to explore whether ISA holds enough potential as an assistive device to justify further research.

2. Material and methods

2.1. Equipment

The equipment consisted of an onboard unit (OBU) that used the GPS position of the vehicle to match its speed to the speed limit (retrieved from a digital map). A display mounted on the dashboard showed the current speed limit. If this speed limit was exceeded with more than 5 km/h the following voice message was given: "50 (the actual speed limit)—you are driving too fast". This message was repeated every sixth second until the speed was below the activation criterion (speed limit +5 km/h). The equipment was essentially the same as that used in PAYS (Lahrmann et al., in press-a, in press-b), except that the display only showed the speed limit and no additional information.

2.2. Recruitment of subjects

Subjects were recruited with support from the local centre for brain injury rehabilitation in Aalborg ("Hjerneskadecentret"). The centre sent out letters to clients who had received rehabilitation at the centre within the previous four years and had retained their driver's license after acquiring a brain injury. A total of 15 persons met these inclusion criteria. Two persons responded and accepted to volunteer as subjects in the study.

2.3. Procedure

2.3.1. ISA driving data

The field experiment was conducted as a single case ABA design. The two subjects had ISA equipment installed in their private vehicle for 30 weeks. The first six weeks served as a Baseline period (A—Baseline 1) during which the speed was recorded, but the user

Table 2
Cross-tab of the independent parameters "intention to speed" and "inattention to speeding", producing four speeding profiles.

		Inattention to speeding	
		–	+
Intention to speed	–	*Profile 1: No speeding* Driver has no intention to speed and driver attends to speeding	*Profile 2: Sporadic speeding* Driver has no intention to speed but driver is inattentive to speeding
	+	*Profile 3: Controlled speeding* Driver has an intention to speed and driver attends to speeding	*Profile 4: Unrestrained speeding* Driver has an intention to speed and driver is inattentive to speeding.