Transportation Research Part F 36 (2016) 6–13

Contents lists available at ScienceDirect

Transportation Research Part F

journal homepage: www.elsevier.com/locate/trf

Reading the situation: The relationship between dyslexia and situational awareness for road sign information

Benjamin Taylor *, Eugene Chekaluk, Julia Irwin

Department of Psychology, Macquarie University, Sydney, Australia

ARTICLE INFO

Article history:
Received 13 April 2014
Received in revised form 10 June 2015
Accepted 20 November 2015
Available online 12 December 2015

Keywords:
Dyslexia
Road sign information
Situation awareness

ABSTRACT

Road signs are tools that provide crucial information to drivers about various roadway situations. Therefore, the present study aimed to assess the levels of 'situation awareness' held by drivers in relation to these signs. This study also assessed the relationship between dyslexia, road sign comprehension, and road sign situation awareness, thus building on the limited research in this area. Drivers completed measures of road sign comprehension and dyslexia. Drivers then completed three drives on a driving simulator; each followed by a probe containing queries about the perception, comprehension and projection of road signs seen in the preceding drive. Situation awareness was lowest at the level of projection. Further, dyslexia was negatively associated with road sign comprehension, and road sign situation awareness, suggesting that the disorder may be detrimental for multiple forms of road sign processing. Implications are provided in the form of a 'SAFE' driver training program that targets a holistic form of road sign processing which takes into account sign meanings in relation to both in-vehicle and outer-vehicle factors; thus encouraging proactive driver behaviour.

1. Introduction

Road signs are tools that aim to provide important information to drivers in a simple and understandable format. In the Australian context they are classified as either regulatory or warning in nature. Regulatory signs provide information about specific roadway conditions that drivers must adhere to, while warning signs provide information about potential hazards (Road & Maritime Services {RMS}, 2014). For example, the 'No Left Turn' sign is regulatory, in that it specifies a particular condition which drivers must obey. Comparatively, the 'Slippery when Wet' sign is a warning sign because it signals a potentially hazardous situation. The two sign categories can be further distinguished by their spatial qualities. Regulatory signs are usually rectangular with white backgrounds, while warning signs are diamond in shape, and consist of black text superimposed on yellow backgrounds (RMS, 2014). The information displayed on road signs can be verbal, pictorial, or a combination of the two.

A large body of research has explored the factors associated with successful comprehension of road signs. Ben-Bassat and Shinar (2006) found that signs which were rated as adhering to the ergonomic principles of sign-content compatibility and standardization yielded the highest comprehension rates. Dewar and Ells (1977) also found that signs that were relevant to the current driving task also yielded higher comprehension rates. Further, a range of other factors associated with successful comprehension have been identified, such as distance and glance legibility (Paniati, 1989), attentional conspicuity (Charlton,

* Corresponding author.

http://dx.doi.org/10.1016/j.trf.2015.11.005
1369-8478/

2006), guessability (Ng & Chan, 2007), and most importantly, understandability (Dewar, 1988; Dudek, Huchingson, Trout, & Chester, 1996).

Poor reading performance, and at its extreme, dyslexia, may be associated with poor road sign comprehension. Developmental dyslexia is a neurological disorder that involves deficits in literacy, co-ordination, and sequencing (Harrar et al., 2014). According to the magnocellular hypothesis, the symptoms of dyslexia arise due to a deficit in M-cell activity during early stages of visual processing (Stein & Walsh, 1997). M-cells are preferentially tuned to low spatial and high temporal frequencies and are thus implicated as being responsible for visual attention (Stein, 2001). Even more recently, a model involving the "temporal sampling framework" (TSF) has been linked to developmental dyslexia and a magnocellular deficit (Gori, Cecchini, Bigoni, Molteni, & Facoetti, 2014). If a deficit in the perceptual magnocellular stream is indeed manifest in poor reading due to problems with making temporal order judgements across eye movements, it follows that other activities that involve temporal order judgements may be similarly impacted. One such activity is driving: indeed it has been suggested that dyslexics may make poorer drivers (Sigmundsson, 2005) and that this is due to the magnocellular deficit. In addition to poorer driving performance, it would be expected that dyslexics and poorer readers would perform relatively poorly on one activity required during driving, namely the successful processing of road signs. Indeed on tasks requiring the differentiation of real and fake road signs within a simulated driving environment, dyslexics performed poorer than controls (Brachacki, Nicolson, & Fawcett, 1995).

Not all researchers in the area of reading subscribe to the magnocellular deficit approach. The phonological theory of dyslexia holds that the disorder arises from deficits in key aspects of phonological processing (Shaywitz & Shaywitz, 2005), beyond the level of perception. For example, dyslexics often have difficulties in connecting letter-sound rules, and breaking up words into their constituent parts (Shaywitz, 2003). These skills are crucial components required in the extraction of meaning from strings of text. Therefore, the difficulties faced by dyslexics may be due to a reduced ability to convert verbal/linguistic stimuli into meaningful information. In either case, however, it should be the case that processing verbal road signs correctly for meaning should be diminished in poorer readers irrespective of whether the underlying mechanism is perceptual (M-cell deficit) or phonological.

As mentioned above, there exists only one study that has investigated the link between dyslexia and road sign processing. Brachacki et al. (1995) found that dyslexics performed poorly on a computerised task involving the differentiation of real and fake road signs. This suggests that dyslexics may have deficits in the ability to extract sufficient meaning from road signs within actual driving environments. However, this study only explored the recognition of road signs. Therefore, there is a still a need for research into the levels of processing that dyslexic's exhibit in relation to road signs. If indeed there is a perceptual/attentional deficit, this should be manifest at a more basic level than that which requires the phonological processing of the sign.

The level that is under current investigation is that of situation awareness (SA). SA may be a crucial component of road sign processing, especially for dyslexics. According to Endsley (1995a), SA exists as a hierarchical construct within working memory that involves the perception, comprehension, and projection of environmental data. For example, pilot SA during flight scenarios involves the perception, comprehension, and projection of display information into situations where altitude changes are required (Jones & Endsley, 1996). Further, the SA of medical practitioners' in emergency situations may involve the perception of patients' oxygen levels, comprehension of the corresponding physiological processes, and projection of this activity into situations where blood pressure may spike to dangerous levels (Wright, Taekman, & Endsley, 2004).

Situation awareness is typically measured with the Situation Awareness Global Assessment Technique (SAGAT; Endsley, 1995b). This technique involves the use of queries at random points during tasks or task simulations. These queries include questions pertaining to the three SA levels, and are developed through an extensive goal-directed task analysis (Endsley, 2000). This analysis involves the identification of major goals involved in tasks, and the underlying subgoals and decisions that are used to achieve these goals. For example, the pilot's goal of maintaining aircraft conformance includes the subgoal of climbing or descending. From this subgoal, a decision to descend can be made, which is then implemented with the aid of the three SA components that are activated in a sequential fashion (Jones & Endsley, 1996; as cited in Endsley (2000)). The SAGAT then measures the presence of these three SA levels in working memory.

The use of three-level model and SAGAT is consistent with a 'product' view of SA. This view holds that SA can be conceptualized in terms of the products of awareness held within working memory (Durso, Rawson, & Girotto, 2007). In contrast to this view is the 'process' view, which conceptualizes SA in terms of the processes through which environmental data is converted into meaningful information (Durso et al., 2007). The process view has been adopted in numerous studies exploring driver SA. These studies have used process indices of performance such as eye movements (Underwood, Chapman, Bowden, & Crundall, 2002) and hazard perception (Underwood & Everatt, 1996) to make inferences about the development and maintenance of driver SA. Notably, Dickinson, Chekaluk, and Irwin (2013) found that a visual attention deficit in novice drivers is due to a lack of SA, as opposed to a limitation in cognitive resources. This suggests that novice drivers lack the knowledge of situations that require greater visual scanning.

The present study implemented a probe technique based on the SAGAT (Endsley, 1995b) in order to measure situation awareness (SA) in relation to road sign information. In phase one, drivers completed measures of dyslexia and road sign comprehension. In phase two, drivers completed three sessions on a driving simulator. After each session drivers completed a probe, containing queries pertaining to the perception, comprehension and projection of road sign displays within the preceding drive. Firstly, it was hypothesised that the three-level model would be applicable to road sign processing. It was predicted that performance scores would peak for perception, and reduce for comprehension, and again for projection.