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Accident ahead? Difficulties of drivers with and without reading impairment recognising words and pictograms in variable message signs

J. Roca [a, *], P. Tejero [b], B. Insa [a]

[a] ERI-Lectura / Dept. Psicologia Evolutiva i Educació, Universitat de València, Spain
[b] ERI-Lectura / Dept. Psicologia Bàsica, Universitat de València, Spain

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ABSTRACT

A timely and accurate acquisition of the information provided by variable message signs (VMS) can be crucial while driving. In the current study, we assess the difficulties of adults with dyslexia acquiring the information shown in VMS and provide evidence to discuss the controversial use of pictograms as potential countermeasures. Twenty-two adults with dyslexia and 22 matched controls completed a simulated driving session. The legibility of 12 VMS was assessed, including six text messages (e.g. "ACCIDENT") and six single pictograms (e.g. the icon for "accident ahead"). On average, participants with dyslexia started reading text messages when they were closer to the VMS. In addition, while approaching text VMS, they dedicated more gazes and manifested worse control of speed. Regarding pictogram VMS, we observed no differences in response distance, accuracy, response duration, or number of gazes. To sum up, the evidence provided reveals that adults with dyslexia, despite potential compensation effects, may still find difficulties reading text messages in VMS (shorter legibility distances, longer reading times, and increased cognitive effort), whereas we found no such differences in the recognition of pictograms (only some difficulties keeping a steady speed). Research on inclusive measures to improve reading in low-skilled or dyslexic drivers must be encouraged.

1. Introduction

Variable message signs (VMS) are a common infrastructure to inform drivers about dynamic regulations and special circumstances affecting traffic, such as variable speed limits, accidents ahead, roadwork sections, queues, or adverse climate conditions. A timely and accurate acquisition of the messages in VMS may be crucial to avoid unnecessary risks and maintain a smooth traffic flow. The current study will analyse the difficulties of individuals with and without reading impairment in accessing the text content of VMS, and will provide new evidence to discuss the use of pictograms as a potential countermeasure.

1.1. VMS legibility

Although a variety of models are currently found along the roads worldwide, a typical VMS layout may include areas to show text messages and/or pictograms (for example, three lines of 12–18 characters each, and one or two pictograms areas at the horizontal extremes). Usually text characters and pictograms are represented using LED dot matrices, such as a 7x5 matrix for each character and a 32x32 matrix for pictograms, although higher resolutions and more flexible layouts (e.g. full matrix VMS) are also common. These resolutions are usually appropriate to show text messages and pictograms that could be correctly identified from a long distance, depending on factors such as character height, lighting viewing conditions (e.g., day or night), font case, and many others (for reviews see, for example, Garvey, 2002; Nygardhs, 2011; Nygardhs and Helmers, 2007; Ullman et al., 2005). Different factors associated with driver characteristics have also been studied, such as drivers with low-vision or older drivers (Garvey, 2002; Garvey and Mace, 1996). However, despite the abundant previous literature that has analysed the legibility of VMS messages as a function of

* Corresponding author. Dept. Psicologia Evolutiva i Educació, Facultat de Psicologia, Universitat de València, Avenida Blasco Ibáñez, 21, 46010 Valencia, Spain.
E-mail address: javier.roca@uv.es (J. Roca).

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different perceptual factors, to our knowledge no evidence has been provided so far on the specific difficulties of people with reading impairment.

1.2. Drivers with reading impairment

Should VMS designers and operators be concerned about drivers with reading impairment? Several reasons would argue in favour of a positive answer. First, it has been estimated that 7% of the population could be considered as dyslexic, a specific learning disorder impairing accurate or fluent word recognition despite adequate instruction and intelligence and intact sensory abilities (Peterson and Pennington, 2012). If we extrapolated this percentage to the driving population in Spain (Dirección General de Tráfico, 2016) and in the USA (U.S. Department of Transportation, 2016), they would potentially represent over 1.8 million and over 15 million of drivers, respectively. In addition, many non-dyslexic individuals are actually poor readers, which are performing in the low range along the reading skill continuum and, therefore, they might also encounter difficulties when reading words in VMS. In fact, most of the measures aimed at facilitating text message reading would potentially benefit not only drivers with dyslexia and low-performance readers, but also virtually any driver trying to read the VMS in cognitively demanding conditions (e.g., dense traffic flow, visual clutter, night driving, reduced visibility, among many others).

Moreover, are adults with dyslexia still struggling to read or did they overcome their difficulties? Previous research has shown that some of their difficulties may be compensated to a certain extent, and there is evidence of neural adaptation and the deployment of compensatory cognitive strategies after behavioral remediation (Shaywitz et al., 2003; Temple et al., 2003). Nevertheless, it is generally agreed that dyslexia persists into adulthood, even in adults with a higher education level and considerable reading exposure (Afonso et al., 2015; Suárez-Coalla and Cuetos, 2015). The difficulties of adults with dyslexia have been confirmed in different languages (see, for example, Afonso et al., 2015; Bruck, 1990; Callens et al., 2012; Nilssen-Nergård and Hulme, 2014; Parrila et al., 2007; Re et al., 2011; Reid et al., 2007; Suárez-Coalla and Cuetos, 2015; Tops et al., 2012; Wolff, 2009), and generally manifest as reading errors and, particularly, low speed when reading words (especially with low frequency or long words), pseudowords (i.e., non-existent words aimed to analyse grapheme-phoneme conversion), or full texts, despite the potential help of the meaning context. It should be noted that slow reading might be of particular relevance in the traffic domain, since it may significantly decrease the legibility distance of text messages in VMS or other traffic signs. However, to what extent dyslexia is affecting the legibility of text messages in variable message signs, despite potential compensation effects, has not been specifically addressed in previous research.

Regarding pictogram-based messages, the use of pictorial information to complement or substitute text is a frequent practice when designing materials for individuals with low reading ability (Houts et al., 2006). Indeed, dyslexia is traditionally considered as a language-based disorder (Peterson and Pennington, 2012) and, consequently, the processing of pictorial information would be theoretically preserved. However, the evidence regarding the benefit of pictorial information on dyslexia or low-skilled readers has provided conflicted results (see, for example, Holmqvist Olander et al., 2016). In particular, recent evidence in the traffic domain has suggested that individuals with dyslexia might also experience difficulties in responding to or understanding pictorial information in traffic signs (Brachacki et al., 1995; Fisher et al., 2015; Sigmundsson, 2005; Taylor et al., 2016). First, Brachacki et al. (1995) presented real or false traffic signs to a group of adults with and without dyslexia. Their results revealed worse discrimination performance amongst the participants with dyslexia, and, in contrast to controls, their performance did not seem to be positively associated with driving experience. Sigmundsson (2005) presented a series of traffic signs to a group of young adults with and without dyslexia using a driving simulator. The participants had to negotiate with real-life traffic situations while keeping the track of a computer cursor marking the position of the simulated car relative to the traffic ahead. The traffic signs appeared suddenly in different locations over the traffic scene, and participants had to detect them. Results in this reaction time task showed that dyslexic individuals had significantly slower responses than controls. This was interpreted, in the terms of the magnocellular theory of dyslexia (Stein and Walsh, 1997), as a worse ability to perceive rapid changes in the environment. Fisher et al. (2015) recruited a sample of non-clinical university students who completed a screening test to assess dyslexia symptoms and a self-report measure of visual stress. They also completed a short simulated driving task that required the appraisal of warning traffic signs to avoid collisions or offence tickets. Regression analysis suggested an association between dyslexia symptoms and speeding in the simulator, although this difference was mainly observed in the dyslexic-prone participants who also reported high visual stress (for further information on visual stress and reading difficulties see, for example, Wilkins and Evans, 2010). Finally, Taylor et al. (2016) also studied non-clinical drivers varying in their reading skill. Their results suggested a negative association between dyslexia symptoms and the scores in a road sign comprehension test.

1.3. Objectives

The main objective of the current study is to assess the difficulties of adult drivers with dyslexia acquiring the information shown on VMS. Despite the potential compensation effects, their difficulties may manifest as reduced reading distances or less accurate responses when reading text messages. Besides, the difficulties may also emerge as a worse control of vehicle speed while trying to read the VMS content, or higher visual attentional resources dedicated to the VMS. In addition, a second objective of the current study is to evaluate a potential countermeasure aimed at reducing the expected reading difficulties, in particular, using pictograms as an alternative to text messages. Different outcomes would be predicted depending on the previous literature. According to the general view on dyslexia, non-significant differences in the recognition of pictogram-based VMS would be found between dyslexic and control drivers. In contrast, considering the traffic studies that report difficulties of low-skilled readers with pictorial information, the participants with dyslexia would also perform poorly with the pictogram-based VMS as compared to the control group.

2. Material and methods

2.1. Participants

A sample of 44 participants was recruited for the current study. Thirty-two were women. The average age was 28.93 (standard deviation, SD = 10.74; minimum, MIN = 18; maximum, MAX = 49). The average years of education was 14.50 (SD = 1.94; MIN = 10; MAX = 18). Thirty-three hold a B category driving licence, which allows driving motor vehicles with a maximum authorised mass not exceeding 3500 kg and constructed for carrying less than eight passengers plus the driver. They had an average experience of 12.43