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The role of drivers' schemes on traffic signs comprehension

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Abstract

Current road signs confront a fundamental issue: are signs displayed in different devices (posted, on-board, painted or electronic) making the most of the same design rationale? Convergent design principles help drivers enjoy an easier coding, learning and retrieval of the schemes enhancing comprehension. This paper focuses on posted road signs (painted vs electronic) that locate events and how well they complement each other. Fixed signage must be the starting point (the scheme formed) to investigate how electronic devices (the new information) can functionally locate variable events or situations.
The paper presents preliminary data regarding a sample of 39 participants. The experimental task consisted of 27 blocks of traffic signs. Electronic-adapted traffic signs were shown to all participants; however, only one group was exposed also to fixed (painted) signs. A 3x2 mixed design was used (experimental condition as inter-group factor and event location as intra-group factor), and in addition, the design also included a working memory measure as a covariate. Comprehension rates were high in all formulas of event location. As previous studies, time response showed higher means when the variable event is located 'between' two referents. Moreover, 'working memory (WM) span' showed a marginal significance with time response. This result leads to an interesting question about the consideration of influence of individual differences in WM capacity when designing complex traffic messages. Overall, results highlight the importance of understanding how complex traffic messages are encoded, processed and de-encoded, and the limits human WM may pose.

Keywords: working memory; schemes; comprehension, fixed signs; variable message signs.

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1. Introduction

In our interconnected and globalized world, it is essential that the main communication routes exhibit effective and functional signage for all drivers (Shinar & Vogelzang, 2013). In consequence an adequate integration of the different road message display devices must be ensured: fixed or electronic panels, on-board systems, etc. At this point considering the characteristics and limitations inherent to the cognitive systems of drivers is essential.

This work addresses the case of electronic signage, specifically, complex traffic signs that inform about the location of circumstantial or variable events (congestion, snow, construction sites). In this type of signal, the content displayed is specific to each situation. This implies that it is not possible to simply 'recover' or 'remember' the meaning from the previous knowledge, but rather that its understanding requires reasoning processes that must be carried out in real time while driving.

1.1. Traffic signs state of art

Despite the importance of traffic signs messages, its comprehension is not always guaranteed (Ben-Bassat et al. 2019; Arbaiza & Lucas-Alba, 2012). Nowadays, a driver can see and understand similar painted signs in different places (68 countries have ratified the 1968 Convention; UNECE, 1968). However, when it comes to electronic devices, design guidelines are not fully developed. Several aspects regarding traffic configurations are established by national regulations, facing less consistency than painted signage (Ben-Bassat et al., 2019). In Spain, electronic signals in the national territory are mainly exhibited in Variable Message Signs (VMS) with a hybrid matrix (Fig. 1b). VMSs inform about possible re-routings or variable events on the road (works, congestion, fog, snow; Arbaiza & Lucas-Alba, 2012), among others. Focusing on painted signs, the Confirmation Signs in particular (CS, Fig. 1a; S600 / S-699; BOE, 2014) have special relevance because they are frequently displayed on the roads, and are the main way drivers learn to locate places in the road network. The CSs constitute the reference matrix through which drivers understand and anticipate situations and events along the network.

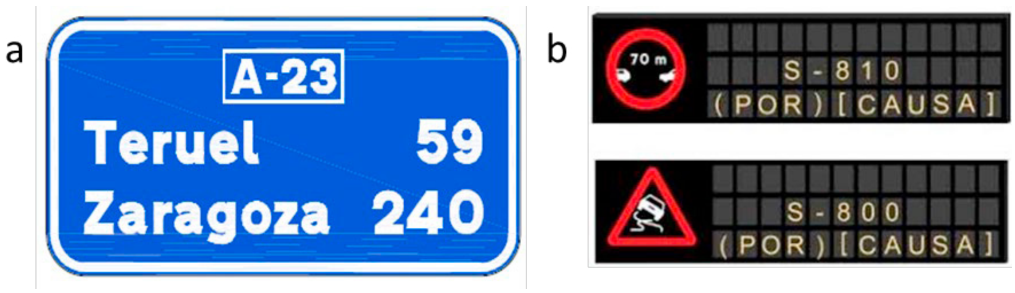

Fig. 1. (a) Confirmation Sign (CS); (b) Variable Message Sign (VMS)

This is a key point since the drivers gains in safety and mobility depend on their adequate anticipation of road situations, including their comprehension of complex traffic signs. This research explores if fixed signs facilitate the understanding of new VMS, which electronic format designs are best suited for integration with existing signage, and the cognitive benefits that a better integration of signalling systems could bring to drivers.

1.2. The role of human cognition: schemes and working memory

According to Carroll (2008), a person is able to understand a situation when she is able to activate a memory scheme to assimilate the coming information. Similarly, we propose CS as the starting point (the formed scheme) to investigate the functionality and comprehension of VMS (new information). One of the VMS functions is to inform about variable events. VMSs display something new when they are presented to the driver. Although some elements can be recovered from the Long-Term Memory (LTM; pictograms, numbers; Arbaiza & Lucas-Alba, 2012), drivers must integrate all the elements (new, known) in real time, and also determine the rules that govern their composition to decode VMSs.

Figure 2B shows an example of a circumstantial event (congestion) located at a distance (31 km), before two reference points (Serrada and Alcores).

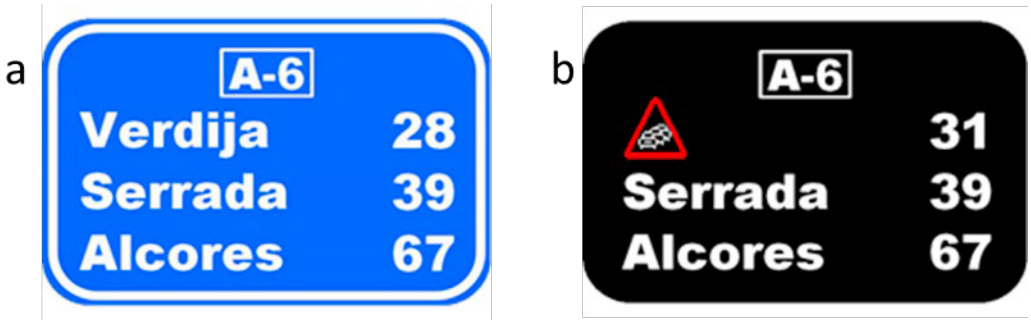

Fig. 2. (a) Confirmation Sign (CS); (b) Adapted Sign from VMS (AS).

Extracting or decoding the meaning of the traffic message implies that the driver must keep the new (circumstantial) elements of the sign active, as well as those recovered from the LTM in WM (Baddeley and Hitch, 1974). This task must be carried out in real time while driving. However, WM has a limited processing capacity (typically, ±7 units, along roughly 30-60s), so the cognitive load should not exceed these constraints (Baddeley, 2000). At some point, individual differences in people's WM capacity may be important too (Just & Carpenter, 1992), so different tasks have been developed to measure WM capacity (e.g., the Reading Span Test; Daneman & Carpenter, 1980).

1.3. The location of variable events

Previous studies have shown a consistent pattern of results in VMS location formulations concerning a fixed reference point (eg, a city). Drivers understood well (comprehension rates of around 70%) that a variable event (congestion, road works) is located 'before' or 'between' cities, compared to events located 'after' a city (30-40% comprehension rates). (Lucas-Alba et al., 2016). In those cases, the formats tested did not include the numeric distance to events or locations, making the information less determined (Tversky, 2005). Incorporating numeric distance, and approaching the ASs structure to CSs one, could diminish ambiguity promoting higher comprehension rates.

1.4. Objectives and hypotheses

This study intends to determine A) if the previous exposure of CS affects the subsequent comprehension of the signs adapted to the electronic format of VMS (AS; Fig. 2b) in terms of comprehension rate and response time; B) if individual differences in WM relate to drivers' performance. We hypothesize (1) that the adapted sign (AS) provides a strong structure obtaining high comprehension rates (higher than previous studies). A ceiling effect on comprehension (no differences between experimental / control) could be observed. (2) The previous presentation of a CS facilitates comprehension in terms of response time. Therefore, the experimental condition (presence of CS) will obtain a lower mean response time compared to the control condition (absence of CS). (3) Individual differences in WM might be related to performance in the experimental task. We expect that higher scores in the working memory measure will be related to a shorter response time. Additionally, there will be no significant correlation in the case of comprehension rate, since the cognitive load involved does not exceed the limits of WM.

2. Method

2.1. Participants

The sample was made by 39 (30 women), between 18 and 35 years (M = 22.36; DT = 4.69), mostly university students (87.2%). Participants were required to be in possession of a driving license (82.1%) or having passed the theoretical part of the driving license. Full drivers were asked how frequent their driving on the highway was; 25.6% indicated 'sometimes' and 38.5% 'often' (the rest indicated 'never' or 'not applicable'); their driving experience was relatively short: 84.7% drove for less than 5 years, 15.4% between 5 and 15 years, and 2.6% more than 15 years. Participants were randomly assigned to conditions, 20 to the experimental group -presence of CS- and 19 to control group -absence of CS.

2.2. Stimuli and materials

To prepare the stimuli (CS and AS traffic signs; Figure 2) place names were extracted from the database of the National Institute of Statistics (INE, 2015). This selection was filtered through the ESPAL database (Duchon, Perea, Sebastián-Gallés, Martí & Carreiras, 2013), in order to control for possible strange variables (word length and familiarity). Thus, 192 place names (outside the region where the study was conducted) remained with a frequency of less than 1 per million words and a length of 3 syllables. One type of sign used as stimuli was based on the CSs mentioned above (Fig. 2a). The characteristics of the format (typeface, size, box, arrangement of elements) of these signs were consistent with what was published in official documents (BOE, 2014). The elaboration of the second type (AS; Fig. 2b) was based on the structure of the CS, adapting it to the electronic format of the VMS. The study was carried out in the facilities of the Faculty of Social and Human Sciences of the Teruel Campus and in the Faculty of Education of the San Francisco Campus, both centres belonging to the University of Zaragoza. In both cases, the table and chair were arranged in the same way, in rooms with adequate temperature and light conditions for the study. All stimuli were presented through MediaLab software (v. 2014).

2.3. Procedure

Upon arrival, all participants received and signed the Information Consent. The total duration of the study was around 30 minutes.

2.3.1. Experimental task

First, they were asked a series of sociodemographic questions (sex, age, educational level, possession of a driving license, frequency of driving on the highway, approximate number of km per year). Subsequently, they were shown the instructions for the task, performed three test examples, and then performed the experimental task. The experimental phase consisted of 27 blocks with two traffic signs (CS and AS) in the experimental condition, and with only one sign (AS) in the control condition. All stimuli were placed in the centre of the screen. The panels were displayed for 4 seconds, an estimated time that traffic signs can be displayed in real conditions at a standard speed of 120 km/hour. After showing the stimuli, participants were required to answer the question: 'According to the sign displayed, where is the event located?', and two response options were offered. The order and display of responses was controlled through balancing.

2.3.2. Reading span test: measurement of verbal working memory

Once the experimental task was completed, the second part of the study began. The procedure to measure WM capacity was extracted from the study by Elosúa, Gutiérrez, Madruga, Luque & Gárate (1996; Prueba de Amplitud Lectora- PAL). This is a Spanish version adapted from the Reading Span Test elaborated by Daneman & Carpenter (1980).

The person responsible for the administration of the study was located to the side, with access to the mouse that passed the screens, without interfering with the direct vision between the participant and the screen. The responses were recorded in a standardized rubric and the data were subsequently coded according to the descriptive criteria proposed by Elosúa et al. (1996). According to these authors, this test requires the two components of WM to be activated: processing and storage. This test shows a relationship with reading comprehension, both components being necessary; therefore, it would be expected that if the information processing in complex traffic signs is based on a process similar to the reading of verbal language it could be reflected in the results.

2.4. Statistical design and analysis

A 3x2 design was used: an intra-subject factor (location of the event: before / between / after), an inter-group factor (presence / absence of AS) and a continuous variable such as covariate (score obtained in WM measure; Elosúa et al., 1996). The dependent variables are: the comprehension rate (measured in successes and errors) and the response time (time it takes the subject to answer since the question is displayed).

3. Results

3.1. Descriptive

Table 1 presents the means and standard deviations of the comprehension rate (correct answers) and the response time, divided by the factors: condition and location of the event.

Table 1. Descriptive measures of comprehension rate and times response.

		Comprehension rates		Response times (ms)	
Factors	Levels	M	SD	M	SD
Experimental condition	Presence AS	.92	.018	2022	136.133
	Absence AS	.92	.019	2120	139.669
Event location	Before	.96	.010	1660	86.214
	Between	.90	.022	2797	133.067
	After	.90	.020	1755	98.641

3.2. Inferential: performance in the experimental task

The results of the statistical analyses carried out in relation to the comprehension rate and response time are presented below. In both cases, a mixed analysis of co-variance (ANCOVA) was carried out with a 3 x 2 design (event location: before / between / after- intra-subject; presence / absence of CS - inter-group) and a continuous variable included in the design as a covariate (score obtained in the WM measure).

3.2.1. Comprehension rate (correct answers)

The analysis does not show statistically significant differences in the effect of any of the main factors or their interaction. Although the main factor ‘event location’ is not significant, when carrying out simple comparisons it is observed that, in a significant way, locating the event variables 'before' a location (M = .96), obtains greater number of correct answers than when it is based on two locations ('between'; M = 0.90) or 'after' a location (M = .90).

3.2.2. Response time

In relation to reaction time, the main factor ‘event location’ shows statistically significant differences, F (2,72) = 59.13; p <.01, ηp2 = 0.62. The relationship observed between the levels of this factor is quadratic, F (1,36) = 90.42; p <.01, ηp2 = 0.72. Simple comparisons show that the differences are found between the level ‘between’ two localities (M = 2797 ms), compared to the other two levels: ‘before’ (M = 1660 ms) and ‘after’ (M = 1755 ms) a locality. Furthermore, the main effect of the covariate 'WM score' is marginally significant, F (1,36) = 2.86; p = .099, so it would be positive to take this influence into account in future studies to see if the trend suggested by these results is confirmed with a larger sample size.

However, the interaction between the covariate ‘WM score' and the intra factor 'event location' is statistically significant, F (2.72) = 5.67; p <.01, ηp2 = 0.14. In order to deepen the relationship between these two variables, this relationship was studied through regression analysis. In this line, it is observed that the variable referring to the scores obtained in the ‘WM score’ correlates significantly with the relative response time only at the level 'between' two locations, of the intra-subject factor 'event location', rxy = -.379, p = .017. The linear regression hypothesis test, through the ANOVA technique, indicates that the relationship is significant, F (1,37) = 6.20, p = .017. Knowing that rxy is the same as beta coefficient, the interpretation of these data indicates that the reaction time increases by a factor of 0.379 for each unit decrease in ‘WM score’. The coefficient of determination, R2 = .120 specifies the gain that we can obtain when predicting a variable using this ‘WM score’ variable.

4. Discussion

The comprehension rates achieved in this study exceed 90% of correct answers, which is a first evidence that this format (AS) could be effective in transmitting the location of variable events according to the usual standards (ISO, 2007). The key is knowing why. As we expected, compared to previous studies, higher rates are shown in terms of comprehension rates (Lucas-Alba et al., 2016). One possible explanation is based on the incorporation of numbers (information on the distance between the driver and the reference) improves the comprehension rate with respect to other VMS formats tested so far, which did not have this information. It seems that the structure and elements incorporated provide enough information to correctly extract the meaning of the traffic sign. According to Tversky (2005), determined information (versus indeterminate) contributes to the ability to build a mental model and facilitates the understanding of the message, reflected in the increase in the rate of understanding.

On the other hand, these results are consistent with previous outcomes: locating an event 'before' the reference point is more efficient, compared to 'between' and 'after' in terms of comprehension. The fact that the format of the AS is so structuring could be promoting that the differences between locating an event 'before' and 'after' are diluted in comparison with other studies (ceiling effect).

On the other hand, it has been shown that subjects take longer to respond to the location 'between' two references. This could reflect a greater cognitive load, since the information of one more element must be processed (my situation as a driver, the first reference point, the variable event, the second reference point). However, it must be taken into account that all the ASs show the same number of elements on the poster and they had the same exposure time. Our explanation is related to reference frames and how these frames can influence our mental representation of spatial information. Anyway, based on the WM model proposed by Baddeley and Hitch (1974; Baddeley, 2000), we hypothesize that an increase in the number of information elements that the driver must keep active on the WM could be causing a greater consumption of time to evaluate the options and extract the correct meaning; being also not very effective (less success rate than 'before').

This is especially relevant considering the relation showed with the WM measure (PAL, Elosúa et al., 1996). Although further analyses and larger samples are needed, this relation has been especially significant on the 'between' level of the event location. Our explanation arises from WM model. According with these premises, it seems that potential individual differences on WM capacity could be more relevant as the cognitive load they must manage increases. Moreover, application to the real context would imply a simultaneous driving activity, so the consequences could be more considerable. These data could show initial evidence of the importance of human cognition in comprehension of traffic signs and, obviously, in their design.

One of the most relevant limitations of this study is the size of the sample. As they consist of only preliminary data, they must be completed with a new data collection, thus achieving greater statistical power. Likewise, including participants from other age ranges and driving experience would also mean an improvement in the robustness and generalization of the data.

In conclusion, communications and technology advance all together to improve road safety and mobility services. Specifically, aspects of human cognition also play an important role in understanding traffic signs. Integrating the different signage systems can be a way to take advantage of previous schema of the conductors to facilitate the comprehension of new electronic formats. In addition, it is essential to understand how the information of these complex signs is encoded, processed and de-encoded; as well as the limits that our information processing systems such as WM may pose. Ultimately, designs consistent with the road environment and drivers' cognition can contribute to prevention and safety in the field of traffic mobility.

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