



A driving-emulation task to study the integration of goals with obligatory and prohibitory traffic signs

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ARTICLE INFO

Article history:

Received 29 July 2009

Accepted 29 March 2011

Keywords:

Traffic signs

Navigation systems

Driver behaviour

Mental models

Mental representations

ABSTRACT

This research aims to analyse how drivers integrate the information provided by traffic signs with their general goals (i.e. where they want to go). Some previous studies have evaluated the comparative advantages of obligatory and prohibitory traffic signs using a judgement task. In this work, a new experimental task with greater similarity to driving situations is proposed. Participants imagine they are driving a vehicle and must make right or left turn manoeuvres according to a previously indicated objective and the information from obligatory and prohibitory traffic signs. Eighty-two participants took part in two different experiments. According to the results, an obligatory traffic sign is associated with faster and more accurate responses only when the participant's initial objective is allowed. When the initial objective was not allowed, an advantage in accuracy was observed with prohibitory traffic signs and there was no significant difference in reaction time between the two types of sign. These results suggest that having an obligatory traffic sign may facilitate a correct response when the driver's goal is effectively allowed, whereas a prohibitory traffic sign could be more effective in preventing error when the driver has a not-allowed goal in mind. However, processing a prohibitory sign requires an extra inference (i.e. deciding which is the allowed manoeuvre), and thus the potential advantage in reaction time of the prohibitory sign may disappear. A second experiment showed that the results could not be explained by a potential congruency effect between the location (left or right) of the road signs and the position of the key or the hand used to respond (such as the Simon effect or the spatial Stroop effect). Also, an increase in the difficulty of the task (using an incongruent hand to respond) affected performance more strongly in experimental conditions that required making inferences. This made the advantage of the obligatory sign over the prohibitory sign in this condition more noteworthy. The evidence gathered in the current study could be of particular interest in some applied research areas, such as the assessment of road traffic signalling strategies or the ergonomic design of GPS navigation systems.

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1. Introduction

Driving is a complex task that involves several cognitive processes (e.g. Groeger, 2000). For example, while driving, it is necessary to properly perceive traffic devices (such as road signs) and to maintain an appropriate state of alertness in order to avoid missing a relevant traffic event. Driving also requires inference processes. For example, drivers have to combine their own goals and objectives (e.g. "I want to go to the railway station, which is to the right") with the information provided by the road environment (e.g. "it is obligatory to turn left") to decide on the most suitable

action for every traffic situation. Thus, some critical aspects of driving could be seen as reasoning tasks, in which drivers must make inferences from pictorial premises (such as the road signs) before carrying out an appropriate manoeuvre. It is necessary to study these perceptual, attentional and inference processes, as well as their interactions, to understand the driver's behaviour in the traffic environment and to design effective road-safety strategies.

Previous research has highlighted the importance of analysing the driver's mental representation of the driving situation. For example, Bellet et al. (2009) developed a theoretical and a methodological framework for studying and modelling drivers' mental representations. According to these authors, drivers' mental representations could be considered keystones in the complex cognitive process deployed to drive safely. Typically, drivers interact with the road environment and build *mental models* of the events and objects that surround them. These mental

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representations are formulated in the Working Memory (WM) on the basis of current perceived information and previous knowledge. The main function of these representations is to conceptualise reality in order to act efficiently, and thus they contain information useful only for the current traffic conditions, in accordance with the driver's goals. The mental representations actively guide perceptive strategies for exploring the environment. They direct behavioural activity in order to ensure the continual contextual adaptation and dynamic regulation of driving. Drivers can also use them to anticipate future events and to analyse the behavioural alternatives available.

In addition, [Castro et al. \(2008\)](#) focused on analyses of the mental representations of obligatory and prohibitory traffic signs. The conceptualisation of the mental representations of Bellet and Castro may be considered complementary in the sense that Castro and her collaborators analysed the representations elicited by some specific components of the traffic environment (i.e. obligatory and prohibitory traffic signs). In [Castro et al.'s \(2008\)](#) study, participants were presented with two successive traffic scenes on a PC monitor. In the initial scene, a vehicle was approaching a T-junction and there was a regulatory sign (either an obligatory or a prohibitory sign) that allowed either a right turn or a left turn (but not both). Then, in the final scene, the vehicle had completed either a right or a left turn and the participant had to evaluate, as quickly and correctly as s/he could, whether this manoeuvre was allowed or not. Reaction time analysis showed an advantage for the obligation sign, but only when the vehicle had carried out an allowed manoeuvre. When the manoeuvre completed by the vehicle was not allowed by the traffic signs, it was the prohibitory sign which obtained a faster reaction time. As a consequence, the authors concluded that obligatory signs elicit a mental representation of the allowed manoeuvre, while prohibitory signs generate an initial mental representation of the not-allowed manoeuvre. This interpretation is consistent with other results obtained in reasoning literature with inference tasks ([Quelhas and Byrne, 2003](#); [Bucciarelli and Johnson-Laird, 2005](#)) and was formally defined as the deontic principle of the Mental Model Theory by [Bucciarelli and Johnson-Laird \(2005\)](#).

Other studies have successfully replicated these results and have also highlighted a particular attribute of the mental representation of prohibitory signs. The advantage obtained by this kind of sign where the participant evaluates the not-allowed manoeuvre could easily vanish when the scene is made more complex (for instance, by adding more traffic signs or more possible roads) or when participants are given further time to think. In these situations, the results showed a clear advantage for the obligatory signs for allowed manoeuvres but a null or negligible difference in reaction time between the two kinds of sign for the not-allowed manoeuvres (for example, [Castro et al., 2008](#); [Vargas et al., in press](#)). Following the Mental Model Theory, the quality of “prohibited” is represented by means of a “mental footnote” ([Bucciarelli and Johnson-Laird, 2005](#)). For example, an obligatory turn-left sign should generate a mental representation of a vehicle located in the left road, while a prohibitory no left-turn sign should elicit a mental representation of a vehicle in the same road, but with an additional “mental footnote” indicating that the situation represented is prohibited. The theory considers that reasoning with “mental footnotes” is difficult. Therefore, under conditions of significant complexity, a transformation might be expected from the mental representation of the prohibited situation to the mental representation of the equivalent obligatory situation. As a consequence, the advantage in reaction time of the prohibitory sign in not-allowed situations may disappear.

A recent work by [Bueno et al. \(submitted for publication\)](#) explored the influence of mental workload when evaluating the

mental representation of obligatory and prohibitory traffic signs. The participants judged whether the manoeuvre performed by a vehicle was or was not allowed according to an obligatory or prohibitory traffic sign. Concurrently, a secondary task was carried out: this could be an articulatory suppression task, a verbal task or a spatial task. The results confirmed the predictions formulated from the Mental Model Theory and showed that the interpretation of traffic signs is more strongly affected by a simultaneous spatial task, particularly in those conditions that require making inferences (such as the allowed manoeuvre and the prohibitory sign condition). According to the principle of iconicity of the Mental Model Theory ([Johnson-Laird, 2006](#)), people build mental representations of the world and use them to infer new information. These *mental models* are iconic, as they represent the main elements of the situation and their spatial relationships ([Johnson-Laird, 2006](#); [Knauff, 2009](#)). Thus, greater interference from a secondary spatial task was expected when the drivers performed the proposed judgement task.

Another theoretical approach to understanding the differences between obligatory and prohibitory signs, discarding their “deontic” character, comes from comprehension studies. The message provided by an obligatory sign (a right turn is allowed) is the negation of the same message given by the prohibitory sign (a right turn is not-allowed). In general, the comprehension of negative sentences is more difficult because it requires more processing ([Clark and Chase, 1972](#)). For example, [Kaup \(2006\)](#) affirmed that when processing an isolated sentence such as *The conductor was not present in the concert hall*, the comprehender first generates a mental representation of a concert hall with a conductor and then a concert hall without a conductor. Kaup et al. called this the *two-step simulation hypothesis of negation* ([Kaup et al., 2007](#)). Note that the response to a situation consistent with the initial affirmative representation might be faster at the first stage (with a short processing time) but later responses will be faster for the negated situation. Therefore, predictions are consistent with the inference view provided here.

1.1. Objectives

Some of the above-mentioned previous studies ([Castro et al., 2008](#); [Bueno et al., submitted for publication](#); [Vargas et al., in press](#)) used a judgement task in which the participants had to evaluate whether another vehicle's manoeuvres were or were not allowed by the road signs. This task proved appropriate for analysing the mental representations of obligatory and prohibitory road signs, although it differed to some extent from normal traffic situations, where the driver has to use the information provided by the road environment to decide immediately on the best action to take, i.e., to generate her/his own manoeuvre. Consequently, with the aim of increasing the ecological validity and applicability of the previous findings, an alternative response-generation task is proposed here. In this new task, to a certain extent more similar to real-life driving situations, the participants have to press either the right or the left direction key according to the road they decide to take, following the road traffic sign (a complete description of the task will be presented in *Experiment 1*).

In addition, in real-life situations, drivers always have to turn the steering wheel to the left to take a road on the left and to the right in the opposite case. Likewise, in the response-generation task, participants have to press the left direction key to take the left road and *vice versa*. However, this way of responding could introduce undesirable congruency effects in the experimental results, such as the Simon effect or the spatial Stroop effect (see, for example, [Lu and Proctor, 1995](#); [Rubichi et al., 2006](#)). These effects may appear when participants are presented with different stimuli that are composed of both a relevant dimension (e.g. the type of sign,

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