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# Cognitive Psychology in Traffic Safety

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## Abstract

Improving traffic safety requires a better knowledge of cognitive science, especially of the cognitive ergonomics of road infrastructure and the vehicle human interface. Driving is a complex task that involves different cognitive modules that have to coordinate simultaneously. Perception, language, memory and mental representation, learning, emotion and motivation, attention, executive functions, thinking and reasoning or motor programing should be better understood in order to adapt traffic infrastructure and interfaces to the human information processing. In this work, we review the importance of these cognitive modes in traffic safety. A holistic exam of all cognitive processes related to driving and road safety is recommended be taken by all governments and in all countries. In this sense, systematic research in driver's evaluation and its link to automobile accidents should be implemented. Driver assistance systems can assist to drivers but they cannot substitute the human processing.

**Keywords:** Road safety • Cognitive processes • Automobile accident • Traffic injury prevention

## Introduction

According to the United Nations (UNs) and its "global plan for the decade of action for road safety 2011-2020" the pillars of activities for improving traffic safety are:

- Building road safety management capacity.
- Improving the safety of road infrastructure and broader transport networks.
- Further developing the safety of vehicles.
- Enhancing the behavior of road users.
- Improving post-crash response.

In this sense, cognitive science can especially contribute to road safety not only in the pillar (d), with regards to human behavior, but in the issues (b) and (c); improving the road infrastructure and the vehicle human interface from a cognitive ergonomics point of view [1].

In order to be able to adapt traffic infrastructure and interfaces to the human information processing, it must be taken into account that driving is a complex task in which different, cognitive modules have to coordinate simultaneously (in a series mode or at the same time). Cognitive resources are limited and required for voluntary control. In this sense, competition between different tasks performances and aims have to be solved in terms of "priority" or to be juggled (keeping in mind that tasks, which require the same cognitive processing, will interfere with each other). As an example, a tracking task will be interfered by a visuospatial task but not by a verbal reasoning task although new findings in driving contexts challenge this view [2].

Driving is eminently visual and the cognitive system must deduce objects movement and depth mainly based on this sense although other perception processes are evidently related to it. Memory plays a role in relating preterit information with the one which is being perceived, by means of their short and long term stores. In this sense, the Short Term Memory (STM) includes the concept of a Sensory Memory (SM), which decays through time. When paying Attention (voluntary action), the sensory information receives a qualitative different processing. This processing constitutes our Working Memory (WM), which deals with information in the present and contributes to store it on our Long Term Memory (LTM), which in turn constitutes learning [3].

With regards merely to attention, there are (at least) two different modes of attentional control. The exogenous type triggers a priming effect, captures attention automatically, and facilitates the processing of stimuli presented at the same spatial area or object (if it is on the move) shortly afterward. In contrast, among other characteristics, the endogenous control develops more slowly and in a voluntary manner. Therefore, attention is more than the plain enhancement of information (taken in the WM), it has a role in selecting information

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from the environment. Regarding the type of attentional cues that can influence on movement (motor programing), lee showed that there are no significant differences in the effect provoked on movement between the endogenous and exogenous capture. In this sense, the attentional cue's meaning is key to trigger the kind movement.

Apart from the episodic buffer the WM is supplied by two sources of information the Visuo-Spatial Scratch Pad (VSSP) and the Phonological Loop (PL) and it is controlled by the central executive. The VSSP reverberates the spatial information in our system in order to work with it, while the PL maintains the auditory material. Regarding the CE, the 12 highest level, cognitive functions ("Executive Functions" (EFs), which lie in the pre frontal lobule) are: (a) spatial span; (b) visuospatial working memory; (c) self-ordered search; (d) paired associates; (e) spatial planning; (f) spatial rotation; (g) feature match; (h) interlocking polygons; (i) deductive reasoning; (j) digit span; (k) verbal reasoning; and (l) color word remapping. These skills are essential for the WM for transforming and operating with mental representations.

When we build mental representations, we are able to think on an "active manner". In the case of reasoning, we envisage possible instances regarding with the meaning of a statement or of a symbol. This semantic representation is as iconic as possible, in form of mental images which structure is analogous to the structure of the situation that they represent. This cognitive process is especially relevant when decoding traffic sing's meanings [4].

## Literature Review

All in sum, we consider that the most related cognitive processes to driving are: (a) perception; (b) language; (c) memory and mental representation; (d) learning; (e) emotion and motivation; (f) attention; (g) executive functions; (h) thinking and reasoning; (i) decision making and (j) motor programing. All of them with automatic or conscious processing in open or closed movements. Obviously, there are other psychological factors (not only the pure manner of cognitive processing) that can influence on driving, such as socio demographic or Personality variables.

### Socio demographic and personality variables

Cognitive processes are modules (or specialized mechanisms) that give solutions in a particular domain regarding specific information. In this sense, in general terms, processing would involve:

- Recalling information stored in our memory.
- Representing it by, for instance, imagining real states of affairs of that information.
- Reaching our goals by solving the laid out problems.
- Learning something new in the process and forming new concepts with it and, finally.
- Making a decision.

First of all, it has to be clear that, all these processes are influenced by peripheral factors, such as socio demographic ones. In this sense, we could precisely define personality holistically as the way we carry out our own cognitive processes. Therefore, before we detail the role of the basic information processing by the cognitive system on traffic safety, we must analyze these other variables and their effect on this matter [5].

### Age, gender, marital status and nationality

The comprehension of traffic signs increases with age. In this sense, young drivers (who have lower levels of education and lower monthly incomes) understand traffic signs worse than adults (with higher levels of education and higher monthly incomes). For women, the understanding of signs does not show significant variation after years of driving experience. However, men with more experience show a significant improvement in the understanding of signals than men with less experience. With regards to the marital status, both single and married people understand traffic signs equally. On the other hand, European and North American drivers understand traffic indications better than those who were Asian and Arabian.

Regarding driving violations, men have higher tendency than women to be frequent traffic offenders. For both, the tendency to commit infractions increases over 35 years old. In this sense, from the age of 40, literature shows that there is a significant loss in the visual acuity, which is related to the deterioration in the sensitivity of contrast to brightness a perception process that underlies this socio demographic point. With regards to vehicle accidents, women (at the same aged than men) have a lower risk of being involved in vehicles collisions. In this sense, the older drivers are the higher likelihood for vehicle accidents they have. Besides, young people are reported to search for sources of stimulation, which drive them to carry out more impulsive behaviors, to take more risks while driving and to be more influenced by their peer group. Regarding the educational level, those drivers who have higher level of education are less likely to be involved in a traffic accident and to have unsafe behaviors when they are being pedestrians. However, when driving, these people take more risky behaviors, even if they are more aware of road safety campaigns.

### Alcohol

Regarding alcohol consumption, alcohol increases Reaction Times (ReTs), impairs motor coordination and information processing, decreases attention and resistance to monotony and increases the risk of accidents. With ethyl concentration between 0.5 g/l to 0.8 g/l, there are alterations in reflexes, motor disturbance and tendency to emotional inhibition, and increases ReTs, euphoria, false sense of well-being, impulsivity and driving aggression [6].

### Personality factors and cognitive style

Personality is an individual manifestation of the cognitive processing style modulated by the environment and culture. Personality structures and determines what we perceive, what we learn from reality, how we adapt our behavior to environmental situations and how we encode, store and use the information previously acquired. Regarding personality factors related to traffic safety, little assertiveness or greater tendency to be suspicious predict the fact of being a frequent offender. In this sense, the lower level of dominance, the higher likelihood of being a frequent offender. On the other hand, the higher level of suspicion and confidence, the higher probability of being a frequent offender. Likewise, social desirability has a positive relationship with adaptive driving and control modes during driving.

Loo conducted a study on personality differences (field dependence/independence) and the perception of traffic signs, in integrated or disintegrated contexts, assessed by verbal ReTs. Field dependence is defined as the tendency by which a subject adheres or not to themselves as a primary reference in any psychological activity. In this sense, subjects who are dependent on the field, rely on external or environmental referents for their performance. Among other characteristics, this processing style means a skill to isolate a detailed feature within an embedded context. This skill takes place in different modes of psychological functioning, not only in perceptual tasks but also in intellectual and cognitive tasks (apart from in social situations). In the literature, personality variables, ReTs and driving records have been related with this mode of processing by using different questionnaires and materials. Among these psychological tools, the embedded figures test the Eysenck personality inventory a driving experience questionnaire and a traffic sign task have been used. The results showed that participants with field dependence had longer ReTs for embedded traffic signs and more traffic accidents than subjects with subjects with field independence. In this sense, extroverted people had longer ReTs to embedded signals, more accidents and more traffic convictions than introverts. These results are in line with the fact that, independently of the age, field independent subjects have lower ReTs than field dependent participants in identifying traffic signs.

On the other hand, subjects with field independence cognitive style are related to a greater difficulty in maneuvers such as joining the road or roundabouts (driving dynamics), more accidents and less perceived safety on the roads. In addition, this kind of cognitive style is also associated with more maneuvering difficulties when parking in public space, less tolerance towards other drivers and less avoidance of road holes; all of them related to external factors [7].

## Perception

Sensation is the connection of our mind with the reality around us through our own body. Perception it would be the interpretation of that sensations in the brain cortex through their integration with each other and with the categories of meanings present in our LTM. The first analyses of the edges, form, size, relative position or depth of the objects are taken through different phases of information processing. Once the mental representation of the object is created another process of decomposition of that object in its primitive semantics is taken. Finally, the ultimate recognition of the object would be carried out through the different levels of the pandemonium analysis giving as a result a merger of all the primitive semantics compared to a model of reference (the category).

This process is not a totally automatic process and it is influenced by the personal context of the subject who is perceiving. However, literature on the role of Perception in traffic safety is based on psychophysics. This kind of studies is focused on the effects of physical object characteristics on the human perception. In this regard, the position a sign occupies, the luminance of the visual scene, the color contrast of the sign (with regards to its surroundings) and the proximity of other signs (which might compete with it for the attention of the driver) can play a role in the ultimate outcome in the processing of the traffic sign. In this sense, it can be found in the literature that drivers obey with less likelihood to a "do not enter" sign when this one is shown merged with its surroundings than when it is isolated by a square.

Regarding the conspicuousness of signs, other factors of important influence on the cognitive processing are:

- The traffic sign size.
- The colors used on it.
- The internal contrast of the sign.
- The symbols integrated on it, although, as we will argue in following sections, this belongs to other cognitive process (Reasoning).
- The support of the sign exhibited in their environment.
- The visual attributes of the pictograph, as well as the properties of the lettering (in the case).

## Response times in the perception of color and size of traffic signs

The time taken to identify traffic signs has been approximately constant through variations in the factors of color and size of signs. However, the proportion of correct answers is larger in small signs for the colors green and red, followed by the medium (normal) and large signs. Similarly, for blue stimuli, this pattern remains, although with smaller proportion of correct answers. A possible explanation could lie in the fact that subjects are familiar with the three colors, since they are all used in vertical signage [8].

## Language

One of the linguistic concepts with the greatest influence on cognitive science is the universal grammar, defined as the innate ability of carrying out structural rules (and ordering objects in the space time continuum), independently of the sensory world. This form of knowledge (usually implicit) is especially relevant for the formal aspect of all kinds of language expression. This function and innate ability has even been from a neuropsychological perspective located in the Broca's area.

Chomsky proposes a notion of grammar that takes into account the tacit knowledge that the speaker and receptor of a given message must "keep in mind" in order to decode language. In this sense, there is an essential difference between the lexical system (which includes procedures that give phonetic, syntactic and semantic properties to the lexical elements) and the grammar rules that integrate this information into a more complex structure of linguistic expressions.

In language development, from an ontogenetic perspective, human learns to produce and understand statements similar to others. In more advanced stages of development, these similar expressions become grammatical symbols, which are represented through sounds with the same phonetic properties. Thanks to the development of the human communication system, the universal grammar allows subjects to order, interpret and code different information materials, such as written, graphic or iconic ones [9].

With regards to the use of different manners for transmitting the meaning of traffic signs, pictograms has been recommended as the most effective mode to transmit information to the drivers in visual degradation circumstances and with elders. However, other

literature points out that text messages in traffic contexts show faster subjects responses than symbolic signs in an identification task. Recent findings have shown no significant differences in the classification of the mental representation of traffic signs taking into account their position the whole ranking of them. Related to the comprehension of traffic signs with symbolic material, some studies have tested the effect of adding text to the signs, in order to compensate the fact that some iconic signs are poorly comprehended. In that case, the non comprehensive signs improved their understandability thanks to the text.

From a psychophysics point of view, readability is understood as the maximum distance at which a driver can correctly understand the meaning of a sign. In this sense, the contrast sensitivity and the degrees of visual angle determine the ability to discern more or fewer lines of text, apart from improving the readability of a given message in specific situations. In this sense, lettering readability of traffic signs is a function of the number of lines presented by the degree of the visual angle with which they are presented. The closer these lines are, the higher its spatial frequency and the less its readability are [10].

## Long term memory, long term mental representation and familiarity

Memory, as long term store retrieves preterit information in the attempt to fully understand the present events. This information must be represented too in the WM in order to be decoded. The mental representation of traffic signs is different among themselves. There are traffic signs that better represent their meaning than others and they can be classified from this cognitive ergonomics point of view there are even certain traffic signs which are more memorable. It is also highlighting that a sign can represent properly its meaning but it can also represent other possible meanings. In this sense, it must be taken into account the univocity of traffic signs, since it can have counterproductive consequences on the normal driven.

In the construction and design of traffic signs, there are clear patterns in the recommendations about how to carry out this task by experts. As an example, the Vienna convention on road traffic defines and classifies vertical traffic signs into three categories, such as informative, warning and regulatory signs. In spite of this fact, governments make different decisions when implementing these signs. This idiosyncratic procedure could respond to the problems when understanding these signs. However, in the legal normative this fact has not been backed up. This particular understanding (depending on cultural factors) is found even when the design of traffic signs is based on semi standardized systems. Regarding this issue, experimental results have shown that the simpler the displays are, the faster Response Times (RTs) and the better accuracy drivers have [11].

Differences in the understanding of traffic indicators are found from one sign to another and from one driver to another. Furthermore, the levels of understanding of the same traffic sign (measured through a short questionnaire and a sign comprehension test) differ in drivers from different countries. For example, in a sample of 1,000 people from Canada, Finland, Israel and Poland (divided by novice drivers, tourists, drivers over 65 years old, drivers with repeated prior infractions, and university students), participants had to express verbally the meaning that they believed each sign had.

In general terms, those who responded best to the test were polish and finish drivers, while the lowest performance was obtained by Canadian drivers. Regarding the differences between the samples, the most significant differences took place within the sample of over 65 years old, where polish and Canadian drivers obtained better results than Finns and Israelis. The most significant result of this research is the fact that there was a better understanding of local traffic signs (shared with the ones of their countries participants come from), compared to those with which the drivers were not familiar. Familiarity with certain traffic signs is a key factor that influences both the understanding and recognition of traffic signs.

This familiarity with traffic signs can also modulates perception attention, mental representation and comprehension from an environmental psychology approach. In this sense, the analysis of the perceived object is based on information obtained from experience. Accordingly, the mental representation that a subject has resides in the interaction between humans (and their LTM) and their environment (currently perceived). These interactions give meaning, codify and evaluate the surroundings. Therefore, mental images are the final stage of perceptual processes, in which they do not comprise only a visual image, but also a synesthetic product. All in sum, the fact of the matter is that there is a need to identify specific cultural and contextual variables when designing traffic signs.

## Learning

In general terms, the more driving experience drivers have, the less probability of having a vehicle accident they got, which is related to the greater perception of risk that more experienced drivers have. In this sense, experienced and new drivers have been analyzed in their ability to perceive objects during a driving situation. In an experimental setting, in each trial, visual driving scenes were presented for 3 seconds. Participants had to analyze the relevant stimuli for driving. Once the scene had disappeared, subjects had to respond in a dichotomous way (true or false) to questions related to the scenes. Drivers with more driving experience have more visual fixations to stimuli relevant to traffic and they lasted for longer. Furthermore, there was a significant relationship between the visual behavior (*i.e.,* the location, number and time of the visual fixation significant for the proper driving behavior) and the accuracy of the responses. Other literature highlights the strongly asymmetric duration of the visual fixation between novel drivers (M=35 ms) and experienced drivers. In this sense, it must be taken into account that accuracy of 100% was achieved with the fixation time of 130 ms [12].

## Emotion and motivation

Anger is reported to be one of the most consistent predictors of aggressive driving behaviors. In this sense, the Impulsivity Sensation Seek (ISS) is associated with expressions of anger and aggression in drivers. In young men, the ISS trait is the only one associated with driving aggression, which could explain risk behaviors. In the case of young women, apart from the aggressive trait, there is a negative effect of the sociability trait, being the less sociable drivers the ones who do not understand properly the faces of frustrations of other drivers (provoking a negative attitude while driving). Finally, for adult women, both aggression hostility and neuroticism anxiety are predictors of aggressive driving behaviors, because of emotional instability, lack of self-confidence and hostility [13].

For women who are not very confident, who obtain high scores in Hostility and who show great intellectual curiosity, a higher level of agitation and more difficulties to concentrate are presented, which would result in the commission of more mistakes on the account of the lack of attention. On the other hand, lapses while driving would be significantly related to depression, anxiety and social anxiety, which provoke a more erratic driving and a higher number of automobile accidents. Similarly, impulsivity and eagerness for adventures are related to more risky behaviors while driving. Driver's anti-normative attitudes are related to having a greater number of traffic accidents. Driver's prudent attitudes have been related to lower levels of anger and hostility and show more respect to other kinds of regulations such as barriers or traffic lights. In this sense, the perception of risk when driving is associated with motivational and attitudinal factors. Subjects, who report feeling more anxious when making a spontaneous and rapid decision (acting impulsively and automatically), are less likely to have traffic accidents. Regarding the assessment of the consequences for transgressing a rule, drivers who do not feel any kind of discomfort doing so have more negative feelings towards other drivers when these ones do not follow their same driving rhythm or speed.

## Attention, working memory and executive functions

Distraction is incapacity to process relevant stimuli resulting in perceptual inefficiency and/or poor response selection. Attention is essential for conscious perception. Therefore, attention guides perception and decides what information will be enhanced in the WM. In turn, attention allocation depends on the WM capacity. In this sense, driving is a divided attentional task, in which several activities must be carried out at the same time. One of the most important tasks is the obtaining of navigation information extracted from the external to the car indicators, which is the primary source of information that drivers receive and which guides their route. In this sense, studies on attention of traffic signs have used driving simulation tasks that vary on difficulty. Since driving involves, among other things, detection, identification and memory, the many these processes have to be carried out, the more WM load and, in turn, the more Attention interfere will be. The WM loading tasks that involve divided attention are the kind of counting or detection, tracking and visual target identification [14].

## Working memory

The clarification between cognitive distraction and cognitive load should be taken first of all in this field. Cognitive distraction can be understood as a more general conception related to the diversion of attention (focusing on a competing activity to driving). On the other hand, cognitive load means the amount of cognitive resources a competing activity to driving demands, being possible to carry out two tasks at the same time (depending on the nature of the tasks and the subject's WM capacity). Classical works have already demonstrated that phonological and visual spatial information interferes each other in tasks when the entity of information is shared. We have the daily example in the situation in which we can carry out a conversation and drive (visual spatial task at the same time, in comparison with the context when we are driving (iconic) and we try to search for our sunglasses within the car (iconic as well).

In this last case, the car deviation from the path we were following until that moment is so likely.

Regarding the experimental effects of WM in driving, literature shows that WM overload reduces line keeping variation increases steering activity, narrows the scanning behavior and makes it drivers focus on the center of the road and, in determined occasions, reduces the speed. In general terms, drivers with higher WM capacity are less likely to distractors interference and, in turn, less susceptible to have automobile accidents.

## Decision making

Previous theories of decision making were developed from logical theories more than from psychological analyses of risk and value. Previous theories were created based on the idea that the world is ideal and the decision maker is totally rational. In the explanation of the human behavior in driving contexts, one has to take into account (not only rational and emotional factors but) incentives and opportunities, learnings (knowing that sometimes they are not adaptive), social contexts in which the driver's behavior occurs or intuitive decisions. The study of decision making in traffic safety does not always calculate the impact of these additional and moreover, determining factors.

Despite the complexity of the cognitive process, the mental workload has been tested in its influence on detection, discrimination and, moreover, decision making while carrying out a driving simulation task. In this sense, the effects of the performance of these tasks incremented participants pupil size, which indicate an extra mental effort and spatial gaze concentration. These mental tasks also produced a reduction of the mirrors and speedometer views. General speaking, when carrying out active mental tasks (such as reproducing information previously attended) the detected targets rate and the correct responses to a decision task decreased significantly, compared with passive mental tasks (such as only listening the audio messages in which the information was given) and with the control condition (with no mental tasks). These errors provoked by distraction hypothetically lead to improper decision makings related to traffic. The interference effect of mental tasks is given because of the redirection of the spotlight of attention to those distractors, which constitutes a decision making itself.

In this sense, the reported increase of spatial gaze concentration means an effective strategy for focusing the visual allocation on the most informative area of the visual field (the road) and this manner, compensate the increased workload due to interfering mental tasks. In real driving settings, eye fixations on roadside advertisements (distractors) are reduced for the better processing of relevant traffic information. Regarding the whole RT the increase of that measure was caused by the fact that targets were glanced at later, less frequently, and inspected for less time in this experimental setting, decision choices were limited to two. In other more ecological contexts with more possible alternatives, the output could probably change.

Mental tasks that require attending to verbal information (such as listening to the radio) do not affect visual behavior, detection or decision making processes. The fact of receiving information while driving (at least neutral with no emotional content and with no need to carry out any action) does not produce distraction.

This is not the same case with "reproduction of information tasks", "dealing with information tasks" (such as a conversation) or "reasoning tasks" (such as having to calculate quantities), with which a significant interference with driving is observed; the interference is based on more the quality and quantity of the task than in the nature (e.g., verbal or visual; as we stated in the introduction). In any case, the lack of real risk (as stated at the beginning of the section) could affect the driver's priority and, as a consequence, the probability of missing some information related to the road and of acting accordantly with that proper information [15].

## Discussion

The Reasoning and their influence on motor programing will be analyzed in the following section. With regards to other EFs that could affect driving, to the best of our knowledge, no study has dealt with the so called "12 pillars of wisdom". Future research should be implemented in that direction

### Thinking as the link between short term mental representation and reasoning

Language acts as the main source (as a window) to provide information for thinking, interpretation and planning systems. In this sense, some studies take the Chomsky's theory as a starting point to establish the relationship between generative grammar and other cognitive processes. However, as we have already stated, language is not the only source of information in driving contexts.

Salcedo et al., highlight the advantage of some traffic signs regarding the circumstances of automobile circulation. In this sense, it is reported that subjects have a greater recognition (which influences, in turn, in deeper cognitive processes) with signs such as trajectory markers, directions information, behavior regulators and warning and recommendation signs. On the other hand, taking into account social contexts, it is reported a better processing of behavior regulators. In this regard, traffic signs are essential in two circumstances.

- When they apply to specific driving situations where regulations are different from other places.
- When there is some kind of risk that cannot be evidenced without the presence of a specific sign.

Therefore, traffic signs are more effective when they meet specific requirements such as satisfying a need, demanding attention, transmitting a clear message, demanding respect from drivers and giving adequate time for a response.

Regarding the mode of dealing with information, although many areas of human information processing must be taken into account Reasoning is considered as the central thoughts active processing. As explained in the introduction of this work, the models theory proposes that every mental model includes the representation of the common features (and their dynamic relations) of experienced entities. Independently of the mode of an expression (verbal or symbolic), the human beings create a mental image of its meaning. In this sense, the semantic information of an expression refers to how many possibilities mental image rules out. Therefore, the greater the number of incompatible situations generated by the expression, the more semantic information that expression provides.

This logic was followed to explain the fact of the faster RTs when evaluating a given "permitted" or "non-permitted" maneuver carried out by a car. By using obligatory or prohibitory, directional traffic signs (before a car turn in a road junction), these authors were able to account for the participants speed of evaluation of car maneuvers; faster when the turn was signaled with an obligatory sign and the car turn was permitted and when it was used a prohibitory sign and the turn was non-permitted. Therefore, when participants are reasoning the meaning of an obligatory, directional sign, they represent themselves (we remind that mental models are dynamic) turning to the correct direction. This manner of processing makes it easier to evaluate a maneuver as permitted (more than as non-permitted) when the turn of the car is actually permitted. On the other hand, when subjects are decoding the meaning of a prohibitory, directional sign, they represent themselves turning to the direction pointed by the sign but labeling as "prohibitory information". Therefore, with prohibitory signs, participants are faster evaluating a maneuver as non-permitted (more than as permitted) when the turn is actually non-permitted.

The influence of reasoning on driving should be deeper analyzed and, moreover, in dynamic experimental settings. The reason for this research line is that, since the mental representation intimately linked to reasoning is dynamic, the testing of these processes should share the same entity than the nature of the cognitive processing. In this sense, the consequence of the mental representation (which determines reasoning) on motor programing have been tested on a series of experiments.

### Motor programing

New findings have shown no significant differences between verbal or symbolic mental representation of traffic signs. These concepts were assessed in a series of studies. In a computer screen, participants had to decide if the definition of a specific traffic sings corresponded or not to an actual traffic sign presented afterwards. The representativeness of signs is understood as the grade to which a traffic sign reflects the main features of its peer population. On the other hand, univocity is understood as the absence of polysemy. A representative sign, before the right matched definition sign, has shorter RTs than a sign that is non-representative. Likewise, a univocal sign, before the wrong matched definition sign, has shorter RTs than a sign that is ambiguous.

Both kinds of traffic signs were introduced on a driving simulation task. The results showed that only non-representative signs produced an attractive, positional effect; attracting participants` movement to the side of the simulated road where signs were presented. These findings highlight the consequences on motor programing of the reasoning with traffic signs (when their mental representation is not clear or, at least, could be clearer). The lack of meaning (relevant for driving) makes participants to get closer to the source of information in order to optimize the probability to decode properly the significant meaning of that source of information. Cognitive ergonomics should analyze, classify, and discard the traffic signs (from the current manuals of traffic signposting) that produce counterproductive effects on movement.

## Conclusion

Advanced driver assistance systems have been further developed in the recent decades. Theses automatic systems help drivers while driving or parking. In this sense, Traffic Signs Recognition (TSR) is a technology that compares the structure of actual traffic signs to sign prototypes, in order to warn drivers about the presence of determined sings in the road. The aim of this warning while driving is to avoid and prevent both traffic offenses and accidents. This computational vision technique allows driving systems to detect road signs and inform of them through sound or visual projection, which adapts to human processing. However, it must be taken into account that, in determined circumstances, the information of in car devices in form of visual displays, audio messages, or other means interferes in the correct processing of other relevant driving information. The literature on this kind of drivers support has mainly focused on the initial detection phases, based on the advantage of color segmentation. The results point out that the color detection strongly depends on the quality of the camera and the light that illuminate signs.

Although driving automatic systems can assist drivers, taken into account the complex cognitive systems detailed in this work, such as mental representation, reasoning or decision making, among others, the human intervention in the driving behavior is indispensable and determining in the output of the whole process. It is essential that the information of road about other vehicles and related to the personal needs of drivers or occupants is integrated and interpreted by humans, in order to reach and take the best option possible while driving. Finally, we conclude that there is a need to evaluate drivers deeper in their cognitive functions in order them to obtain their driving license. Current driver's assessments spin around narrow and partial cognitive processes. A holistic exam of all the cognitive modes related to and significant for driving and traffic safety must be taken by all governments and in all countries. Therefore, a systematic research in this kind of evaluation and its link to automobile accidents should be implemented to clarify the weight of each cognitive processing and their relationship between them.

## Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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