External and Internal Representations of Road Pictographic Signs

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Abstract: Contrary to novice drivers that learn the univocal meaning of road signs, expert drivers get low scores about the meaning of road panels that are made of icons and of graphic signs. This is a surprising case of practice lessening performance. We argue that the meaning of road signs is built in the context of the driver task and in the context of the current road situation. We have run an experiment that show that expert drivers fail to the "what does it mean" question when road signs are displayed in isolation or in the context of a real road situation, but they succeed to the "what to do" questioning. We described the whole set of 300 road signs both from their surface properties (form, color, icons, …) and from the required actions. The road signalization system appears to be a complex system that is not fully coherent since surface properties partially match the corresponding actions properties. Finally, we advocate that contextual graphs capture the effects of task and road context, as well as the automatization and proceduralization processes since it allows encapsulation of action sequences.

1. Introduction

Road signs are made of icons and of graphic signs. Contrary to words that are recognized as symbols (one word, different meanings), icons and graphic signs are supposed to have a unique coded meaning: icons because they are analog of what they figure or indicate; graphic signs because they are used for a unique meaning (one sign, one meaning). Thus, the design of "a cow" (see Figure 1-a) means a "cow", and a red triangle means "danger", while a red circle means "interdiction": "a cow on a red triangle" would mean "cow danger" (Figure 1-b), "a cross on a red circle " would mean "interdiction cow" (Figure 1-c).

Such road signs are seen by many linguists as a complete language and analyzed that way, each component of the road sign having a semantic function. As a result, Droste (1972) considers a road sign as an entire sentence and then a logic proposition that drivers can model in their decisions or not.

However, the meaning of linguistic sentences vary depending on the context, if we assimilate the meaning at inferences drawn from the text. For instance, the sentence "*Mary closed the door*" can be a cue indicating that Mary has entered

the room ("*Near her house, I saw that Mary was followed by a strange man. In hurry, she runs. I felt happy: Mary closed the door*"), has left the room ("*I saw that Mary was late. She was in hurry. I felt happy at nine: Mary closed the door*"), was angry ("*I saw that Mary does not agree when she stands up. A moment later, everything was said: Mary closed the door*").

Similarly, note that Figure 1-b means "danger *because of* cows", not "danger *for* cows", and Figure 1-c means "interdiction *for* cows", not "interdiction *because of* cows": the relation between components is an information that is not provided by the road sign: the whole of the Icon is more than the sum of its parts (Harmon and Julesz, 1973; Szlichcinski, 1980). Given that object category (commonalities of possible instances) and action (at least two states of an event) cannot be pictured in static visual images, components of road signs are to be understood in context. In fact, signs do not provide their intended concepts and action, even when the pictured objects in icons are easily recognizable. Moreover, while incorrect interpretation of road rules has potentially serious implications on road safety outcome, according to inquiry results, most of the drivers do not match road signs with their intended meaning.

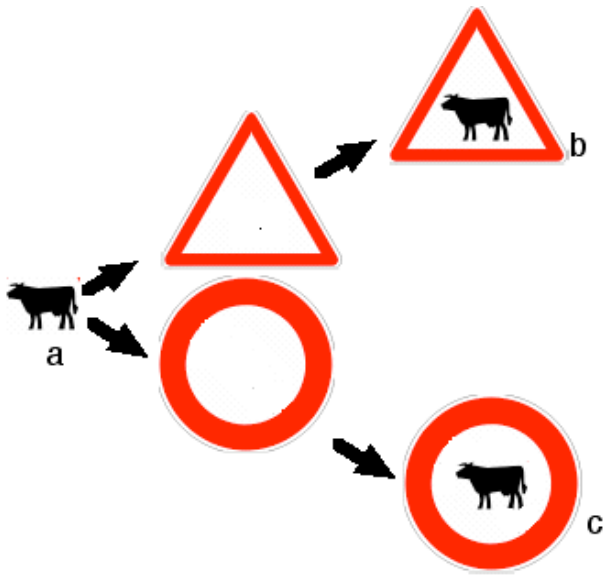

Figure 1. The making of a road sign: design of a cow combined (a) with a "danger" sign, would mean "danger because of cows", (b) with an "interdiction" sign would mean "interdiction for cows".

In short, road sign usability brings up two questions. The first one concerns the readability of visual signs with a rather complex semantic. The second ques-

tion is related to the context in which drivers are invited to conform to what it is expected. As for linguistic sentences, the context in which road signs are perceived is an important element of the usability of the road signs. We advocate that the context help making inferences in order to understand road signs. We consider that (1) the understanding of a road sign is mainly contextual, (2) the understanding of the road-sign meaning depends on the environment, and (3) decision making depends both on the contextualized meaning and on the task at hand.

Hereafter, the paper is organized in the following way. The first part of our paper reports data from an experiment we run in order to correlate the number of years of practicing driving a car with the "what it means" for road signs. The second part focuses on the presentation of the external pattern of road signs setting up, in particular, a tree representation of road signs external pattern. In the third part, from the road task needs, we try to explain how the conversion of formal meaning is done to a procedural meaning in connection with the context of driving activity.

2. Are road signs correctly interpreted?

A road sign expresses a message sent toward road users; the message is an order to perform a behavior about an object. Orders could be divided into several action categories to perform (not to go, to over pass, reduce speed…) and a lot of objects for which actions are to be applied to (animals, the value of a speed, other road users…). Because of the car speed and the multilingualism of road users, there is a set of constraints the messages have to take into account when they are conceived. So that the drivers give the appropriate meaning to the message, the road sign conception has to clearly evoke the item, that could be an object or an event, in the way there is an immediate understanding, out of the verbal language, however minimizing inferences drivers need to understand it.

Our first hypothesis is that the understanding of road signs is context dependent. If so, drivers with many years of practice should not respond correctly about "what does it mean?" when presented road signs alone, without context, contrary to young drivers that just learn the road signs meaning. Displaying road signs in the context of road situations should improve performances of practiced drivers.

Second hypothesis is as follows. We reasoned that because young drivers have the greater amount of road accidents, they should have a less greater amount of correct responses than experienced drivers, when questioning about

"which action is to be performed?" especially in the context of real road situation.

This is a known fact that drivers fail to respond correctly to the road signs meaning. What is novel is the correlation between years of practice and road sign meanings, as well as questioning both about the "what does it mean?" and "which action is to be performed?"

In one of the experiments we run, more than 123 participants were asked to respond on 40 road signs. Participants were ranked given the number of year of practice: 21 have no license, so they do not drive, 25 were two years long in practice, 23 had between 2 and 5 years of practice, 24 between 5 and 10 years and 30 were more of ten years long in practice.

Half of the Participants were given 20 road signs alone, then 20 road signs pictured in a real road situation. The other half was presented the road signs in the reverse order. In each group, half responded first "which action to perform when seeing the road sign?", then "what does it mean?". The other half was questioned in the reverse order.

Results shown in table 1 indicate that young drivers (less than two years of driving) are quite well responding when the road sign is displayed as in the "learning-to-drive" book. They also provide the corresponding right actions that are to be performed. Another result is that higher is the number of practice, lesser is the percentage of correct responses both on the meaning and on the driver's action.

The same pattern of results is observed when questioning about the "what does it means" when the road sign is displayed in the context of a real road situation. In opposite, responses of all the participants were quite perfect about "what to do" when facing the road sign in a road situation.

	Do not drive	less than 2	2 to 5	5 to 10	more than 10
Road sign alone / What does it mean ?	0,66	0,89	0,76	0,71	0,68
Road sign alone / What to do ?	0,65	0,94	0,74	0,67	0,47
Road sign in context / What does it mean ?	0,83	1,00	0,73	0,50	0,43
Road sign in context / What to do ?	1,00	1,00	0,90	1,00	0,86

Table 1. Percentage of correct responses when road signs are displayed in isolation or displayed in the context of a real road situation, and when the questioning was about "what does it mean?" or "which action is to be performed?"

In short, what we found is that the practice of driving cars does not improve the understanding of the meaning of road signs. Much more, the number of years of practice is inversely correlated with the understanding of the intended meaning: more one drives, less s/he is able to correctly respond to the meaning of road signs. Second important result is that, in the context of a real road situation, everyone knows what to do when facing a road sign.

In order to capture the information content of road signs (which information is displayed, which information is not displayed), we analyzed what a road sign is made of, using tree properties (Poitrenaud, 1995), and in order to understand the role of the context in decision making in real road situation, we modeled the driving situation, using contextual graphs (Brezillon, 2003).

3. What is a road sign made of?

From an historic point of view, how semantization process of road signs evolved through years can be found in Krampen (1983). First use of road signs, one century ago, was to help drivers to manage with network dangers and road rules. There were four signs, each one indicating a danger on the road ahead: a curve, a railway, a crossroad, and a bump. It was later decided that an iconic international language was the best way to inform drivers. As years went along, car number beginning to be larger and larger, it was necessary to standardize road signs both between them and within the road network. As a result, new road signs were created to express not only danger location, but also several new categories of information and new actions.

To do so, conceived with a combination of three components (shapes, colors and icons), road signs denotes information categories in such a way a traffic regulation rule, as a whole, can be expressed by signs from a matching of colors, shapes and icons. Shapes and colors are organized to indicate the category of action to be undertaken: to do, not to do, stop to do, stop to not do. According to them, text or icon point out the subject or the object of the action. For example, "a pedestrian into a red triangular sign" means "car drivers have to manage their run with pedestrian crossing ahead on their track"; "a pedestrian into a blue sign" means "pedestrians have to walk on this way and none other one".

The whole set of road signs appear to be a result of both history and standardization. The contemporary set of European road signs is of about 300 panels that are categorized according to typology based on the type of displayed information: localization, dangers, obligation, prohibition. Tijus, Chêne, Jadot, Leproux and Poitrenaud (2001) proposed a general taxonomy based on implication: indication of dangers implies localization of the danger, and that obligation and prohibition are for avoiding dangers.

Because the Tijus *et al*. (2001) taxonomy did not explicitly relate to the actual road signs, we described the whole set of 300 road signs as an attempt to capture the internal structure of the road signs as a whole. From a semantic point of view, each sign can be described from one tree of properties. We take into account four types of properties: (i) surface properties that correspond to the

shape and color of the sign, (ii) the label of the sign that indicates its function, (iii) the category of action concerned (information, danger, prohibition, obligation), and (iv) the object on which the action is to be applied.

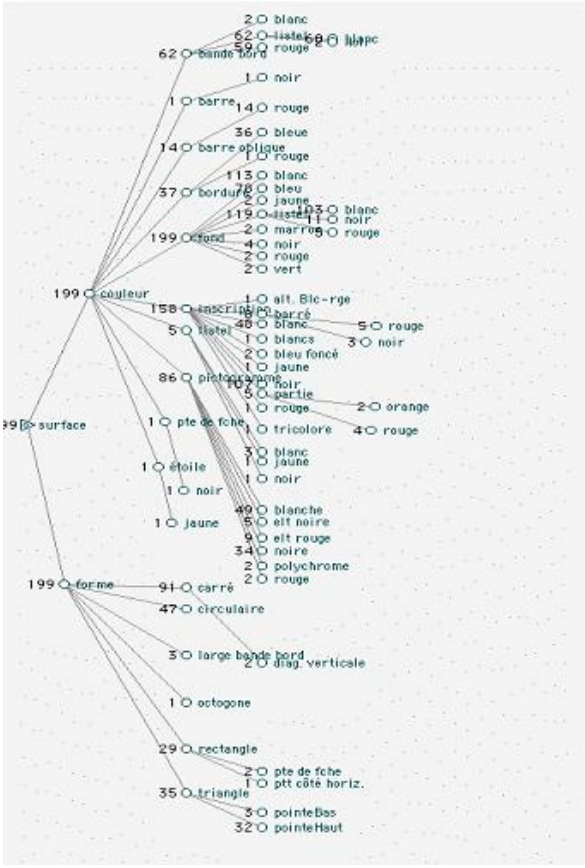

Figure 2. The taxonomy of surface properties (shape and color) of 199 road signs.

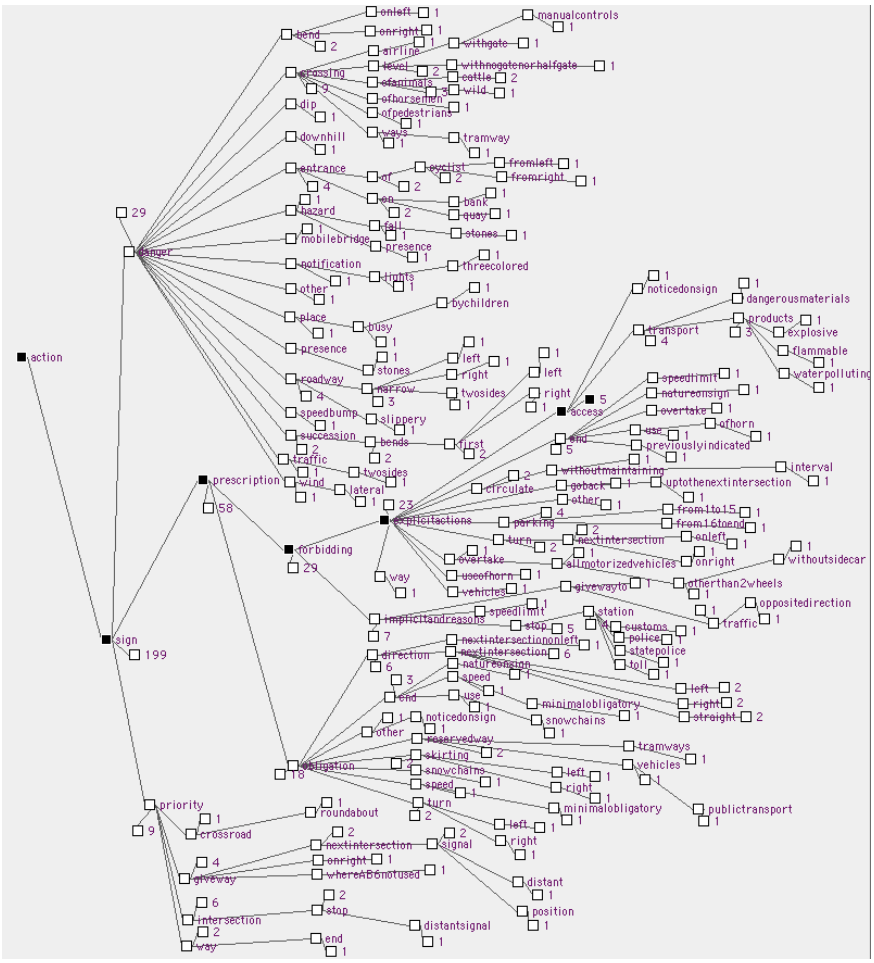

Figure 3. The taxonomy of action properties of 199 road signs.

Signs are aimed at pointing out properties of the road network the driver has to cope with. To do so, visible surface properties (shape, color and icon) is to be connected to one action category to perform. A first category of visible properties is about location, and how to reach it (a rectangle with an arrowed side). A second is a specific danger the driver will have to cope with (a red triangle). The third is aimed at forbidden one specific behavior in opposite with the network organization (a red circle). The forth is obligation of an action (blue circle).

Using the tree properties formalism (Poitrenaud, 1995), Figure 2 shows the taxonomy of surface properties and Figure 3 the taxonomy of action properties for 199 panels of danger, prescription and priority.

The main result is that the surface description does not match the action description, either for shape or color. This means that to a same class of actions corresponds different shape, or different colors.

Moreover, for driver's interpretation and decision making, depending the sign category, ambiguity differs. First, the action is more or less explicit. For example, the meaning of the triangular sign whose icon shows a car falling down from a bowery might be: "*take care of your track, you can fall down into water*", or "*the way ahead is an impasse, if it is not your destination, your way is wrong*". In fact, about danger signs, the driver has to infer the action to perform, connecting both the current action and the specific danger. With signs of circular form, the action that is obvious to perform has not to be decided. But it is unclear which road user is concerned. For example, the sign showing "*two cars whose left one is red*" means that "*a car is not allowed to underpass another car*": does it means that a motorcycle or a van can do it?

As for any system, there is logic of conception (the point of view of traffic authorities) that might differ from the logic of use (the user's point of view). Contrary to traffic regulators, the driver has to understand what the road sign means in the context of the actual road situation and in the context of her task. How it is possible to ignore the right meaning of road sign and being able to perform the right action?

4. Road sign interpretation as contextualized inferences

When learning to drive, surface information is connected with both invisible safety and legal information. The former is justified by the fact that, if they don't agree with a message they are concerned by, they could make an error and even have a crash. The later means that police could punish them if they contravene the message.

Learning to provide a road sign with its safety and legal information is a complex process in itself, as shown in Figures 2 and 3. It may be that this is not the same learning process that occurs in the task of driving, given that novices who know well what a road sign means and what action to perform are responsible of more accidents than expert drivers who ignore the road signs meaning although they respond well about which action to perform.

Drivers do need information in case of doubt on the issue of the situation they perceive, and then road signs are useful when connected to the search and to

the current activity (Allen, Lunenfeld and Alexander, 1971). Thus, there are at least two contexts that intervene in the process of understanding a road sign: the environmental context and the context of the task at hand.

The environmental context in which the sign is perceived determines the meaning. For example, as a simple case, "*a curve in a triangle*" means that the speed must be reduced because the road is going to bend. Such information could be redundant if the curve is perceived. It could be in opposite if it announces a further curve on right while located on a curve on left. In addition, the driver will not behave in the same way if the sign is located just at the beginning of the curve, if the curve is further, or if, because of the traffic for example, the speed is yet reduced. Information provided by the road sign is context dependant.

The task, in which the driver is involved in, affects also the process of the road sign information. The driving task is composed of a series of subtasks aimed at one goal that is to reach destination (Allen, *et al*., 1971). Cambon de Lavalette, Tijus and Leproux (2003) have found that Inference making from Electronic Road Sign was based on the interpretation of how the electronic device functions, related with the task at hand.

Dubois and Fleury (1987) have developed a theory of the driving task connected with environment characteristics. According to the environment, the driver builds a representation of the situation he has to manage with. Information provided by the environment, such as road signs information, is connected to the task representation. For example, one subtask category is «town gate»; when it is activated, drivers will search information on speed to follow, on other road users such as pedestrians, on one-way roads, and so on. It follows that information that do not meet the task requirements is not as well processed as information that can instantiate the task variables. Thus, a mismatch can occur between the task context in which the driver is involved and the environmental context in which the road-sign is embedded.

In order to understand the gap between explicit knowledge about road signs and the implicit knowledge that is used when driving, this gap increasing with years of practice, we model the driver decision making as a contextualized interpretation of a given sign, at a given moment, in a given situation. This is related to the well-known problem of the difference between the prescribed task and the effective task, the difference between the procedure and the practice, etc. The latter (effective task, practices, etc.) correspond to a contextualization of the former (prescribed task, procedure, etc.).

We use a context-based formalism called Contextual Graphs (Brézillon, 2003) for modeling the implicit knowledge encapsulated in situation that helps decision-making. What contextual graphs model is the building of a "chunk of knowledge" called *proceduralized context* by formalizing a temporal sequence of

diagnosis and actions, the different ways to reach a goal, and the elements for choosing an action sequence.

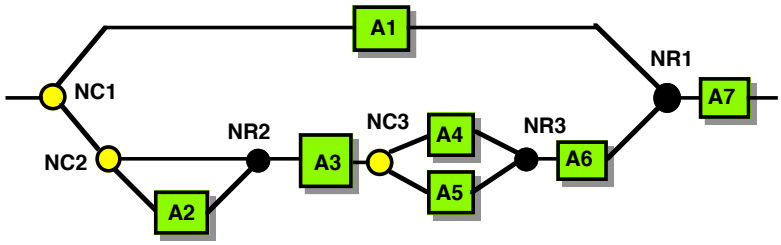

Figure 4. The whole set of possible decision-action facing a "Curve on the right" road sign as formalized in a Contextual Graph. Legendary: - NC1 (Contextual Node 1): Do I see the road sign? - A1 (Action 1): No, then I keep the same behavior, - NC2: Yes, do I recognize it? - A2: No, then I need to identify it from the situation, - NR2 (Recombination Node 2): I do recognize the road sign, - A3: I have to find the situation corresponding to the road sign, -NC3: What about the distance to the obstacle? - A4: The obstacle is close: I have to focus on it immediately, - A5: The obstacle is far: I first suspend other actions, - A6: I reduce my speed, in order to… - A7: …turn left.

Figure 4 represents several possible actions due to practices of a driver arriving at a road sign "Curve on the right": (i) First the driver detects the "danger (curve on right)" road sign, (ii) the driver identifies the road sign in context, by analyzing the road situation, (iii) s/he interprets the road sign as possible actions in this context, evaluating the distance to the event that is pointed out by the road sign, (iv) the driver reduces the vehicle speed, (v) the driver is then able to deal with the curve on the right.

Once the road sign has been detected (contextual node NC1), but before a full recognition of the road sign (NC2), a driver that uses frequently a given road will recall his usual practice automatically. This encapsulated knowledge is modeled by conceptual graphs by adding a NC4 node between NC1 and NC2, and a NR4 node between A6 and NR1: "Known part of the road?" Two branches will then be added: a branch with NC2 if the road is not known, branch with Activity 1 "Do automatically what I do usually" if the road is known. The road sign doesn't trigger an attention reflex but the set of an automatic driving procedure.

5. Conclusion

Contrary to novice drivers that just learn the driving rules and the road signs codes, experienced drivers did not provide the meaning of road signs seen in isolation. However, when they see the road signs in the context of a real road situation, they know what action is to be undertaken. For who is interested in the cognitive process of visual information, this is an interesting dilemma.

First, because a static visual message cannot represent a category (commonalities) and actions (events), we advocate that iconic information is not univocal "one sign-one meaning" and, as verbal message, the meaning of a pictogram is built in context. We run an experiment and we found that, when they see the road signs embedded in pictures that displayed real driving situations, expert drivers provided the correct driving action. But, they still fail providing the "right" meaning as defined by the driving rules of the Highway Code. In a further analysis, we intend to analyze the responses experienced drivers provide when asked "what does it mean?" But what we already know is that responses vary with context.

Second, cognitive research must explain how people are processing visual information in context and how they make decision. The driving situation is again an interesting topic since the processing of a road sign might vary from a zero-process degree to a problem solving degree. For instance, many of the road signs that a driver encounters are outside the current task (road signs located on other roads, or located on further apart section of the road, that the driver will not take). The road course might also be so well known that an automatic driving occurs with no control process. In other cases, road signs could be processed in situations in which they appear to be out of affairs. For instance, when a road sign requires reducing speed although speed is yet reduced. Sometimes, however, to find the significance of a panel is a problem to be solved. For example, when a panel indicates the permission to park one week out of two in a street with prohibited direction, or when a mountain road sign indicates "risk of fall of stones": should the driver accelerate, decreasing the risk of receiving a stone, or should the driver reduce its speed to avoid blocks of stones on the road?

A model of the driver must be able to dynamically simulate the understanding of road signs in context, both the context of the task and the context of the current situation, and the decision making which results from processing road signs in situation. We have shown an example about how contextual graphs (Brézillon, 2003), that condition actions with types of context, and encapsulate sequences of condition-action, in a time-scale description of procedures, furnishes an adequate formalism. Next step of our research is to describe and simu-

late drivers decision-making facing the same road signs in different task contexts.

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