MODELING DRIVERS' DECISION-MAKING PROCESSESES FROM ROAD SIGNS

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ABSTRACT

Road signs aim at expressing a message to road users in the form of actions about objects. For one given sign, both actions and objects are well determined because legislated. However, it is well known that the road users do not respect systematically those laws. So, the issue of this contribution is why does the observed decision-making vary from the expected decision-making and why do not road signs fill their role in this process? We reasoned that a first step to study this gap between expected and observed behaviors could be comparing expert and novice drivers (whose behaviors differ on the road). A second step would be to study the device itself by building an ontology of road signs. Finally, because understanding is context-dependent, we propose to use a context-based formalism of representation called Contextual Graphs for representing and interpreting drivers' behaviors.

KEY WORDS

Road signs, procedures vs. practices, decision-making in context, contextual graphs.

INTRODUCTION

Road signs were first used in the late XIXth century in order to solve problems due to the inadequacy of the road system to the new performances of motor vehicles (Krampen, 1983; Cambon de Lavalette, 1999). With accidents getting more and more significant, a highway code became necessary. Then, road signs express locally laws of this code. Because of (1) the multilinguism of road users and (2) the potentially problematical conditions of visibility (depending on the speed, the weather, the state of the sign, and the profuseness of stimuli in the environment), the message is expressed in an iconic format. Those are the constraints that road-sign designers have to cope with, given that drivers when confronted with a road sign should provide a rapid response based on an immediate capture of its meaning.

Then, road signs are seen as one of the first tools aiming to provide a moving and safe traffic regulation. However, it is often claimed that road users have a poor knowledge of their

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exact meanings. As a consequence, observed behaviors in traffic may vary from the expected behavior, producing misuses and crashes into the road network.

In the two first parts, we study the logic of functioning of the system of road signs with questions such as what are road signs? What are they made of? What kinds of messages do they hold? On the third part, we'll deal with the logic of use: Do the road users receive the message of road signs as expected and what do they do with those obligations? We see that the drivers' behaviors are based on the context of their current task rather than on the legal message expressed by the road signs. Finally, we'll propose a formalism based on context that allows us to model the decision-making process of a driver engaged in a specific situation and facing a given road sign. The Contextual Graph formalism is described in (Brézillon, 2005).

WHAT IS A ROAD SIGN?

Because they are the expression of the law, road signs should be univocal. But the message provided to road users is a complex one. According to Droste (1972), a road sign differs from other sign because it doesn't represents a single word but a sentence, a proposition. It is then carrying many elements of information, which is a source of ambiguity.

Theories of situation models (see van Dijk or Zwaan, 2002) have shown that when they have to understand a given situation, people need few information to address questions: Who, what, when, where, why and how. We showed that the three main dimensions are (in order of importance) the action, the object and the agent (Bazire, 2003). Each road sign need to precise at least those 3 components (see figure 1).

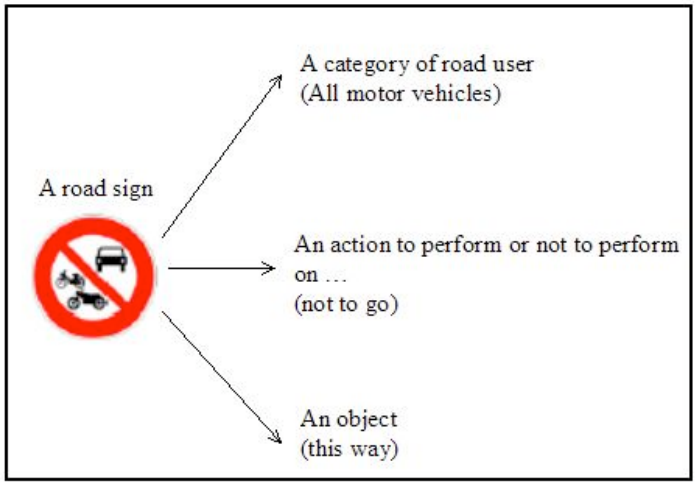


Figure 1. The 3 components of the message conveyed by a road sign.

The first question a road user has to answer when facing a road sign is: Am I concerned by this message? So road signs have to express clearly the categories of road users. Designers use then a system based on metonymy: some icons stand for super-ordinate categories (for example, the car icon means all four wheels drivers and not only car drivers).

The actions that have to be performed are various, such as not to go, to over pass, reduce speed, park. Note that certain actions are not well defined, consider the fall of stones sign: does the driver have to increase speed in order to avoid falling stones or does he have to reduce speed to avoid the stones already fallen on the road? What about the following sign?

Figure 2: The signal "Attention, proximity of an airport" alerts for a very exceptional danger for the driver.

As for the actions, there are a lot of objects for which actions have to be applied to: animals, the value of a speed, other (category of) road users, a way, etc.

Because of the possible ambiguity of such iconic messages, most[1] road signs respect a grammar (see Droste, 1972 or Meunier, 1988) that matches a shape (circle, triangle or square), a background color (blue, white), a frame color (red, white, black) and an icon. Shape and colors express the kind of action expected (pay attention → reduce your speed, don't, etc.) and the icon stands for the object (reduce your speed under the limit of) or the category of road user concerned by the message (e.g. see Figure 1). This category can also be more specified in a second sign. The combination of those elements allows a great amount of messages (see Figure 2, for an example).

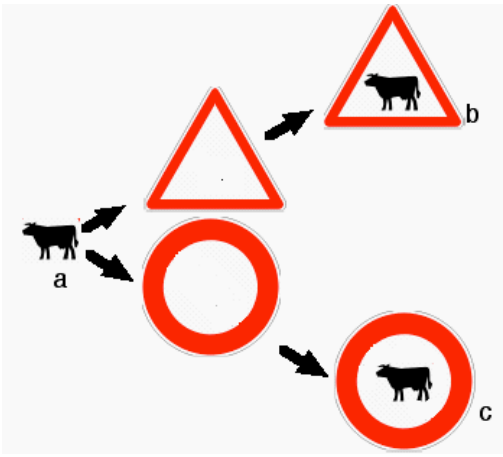


Figure 2. The different meaning of a message in a road sign according to the presentation.

The "cow icon" (which stands for any cattle) combined with (b) a red-bordered triangle means that there is a danger *because* of the eventual presence of cattle on the road, or with (c) a red-bordered circle, would mean that this way is forbidden *to* domestic animals. Note that (b) could be "Danger for cows" and (c) could be "forbidden because of cows": the icon can express the object or the user.

[1] "Most" because few (historically, the fisrt ones) have a unique shape, such as the stop.

We have seen here that a road sign is a complex message and then can bring many sources of ambiguity and notably on the behavior that is expected.

AN ONTOLOGY OF ROAD SIGNS

But do the road users know about this combinatory? And does this combinatory preserve the message from equivocal understandings? In order to answer the last question, we computed ontologies of road signs, by describing the whole set of 300 road signs, both from their surface properties and from the required actions, using tree properties (Poitrenaud, 1995). Figures 3 and 4 show those two ontologies. The aim of this work is to discover the coherence of the device.

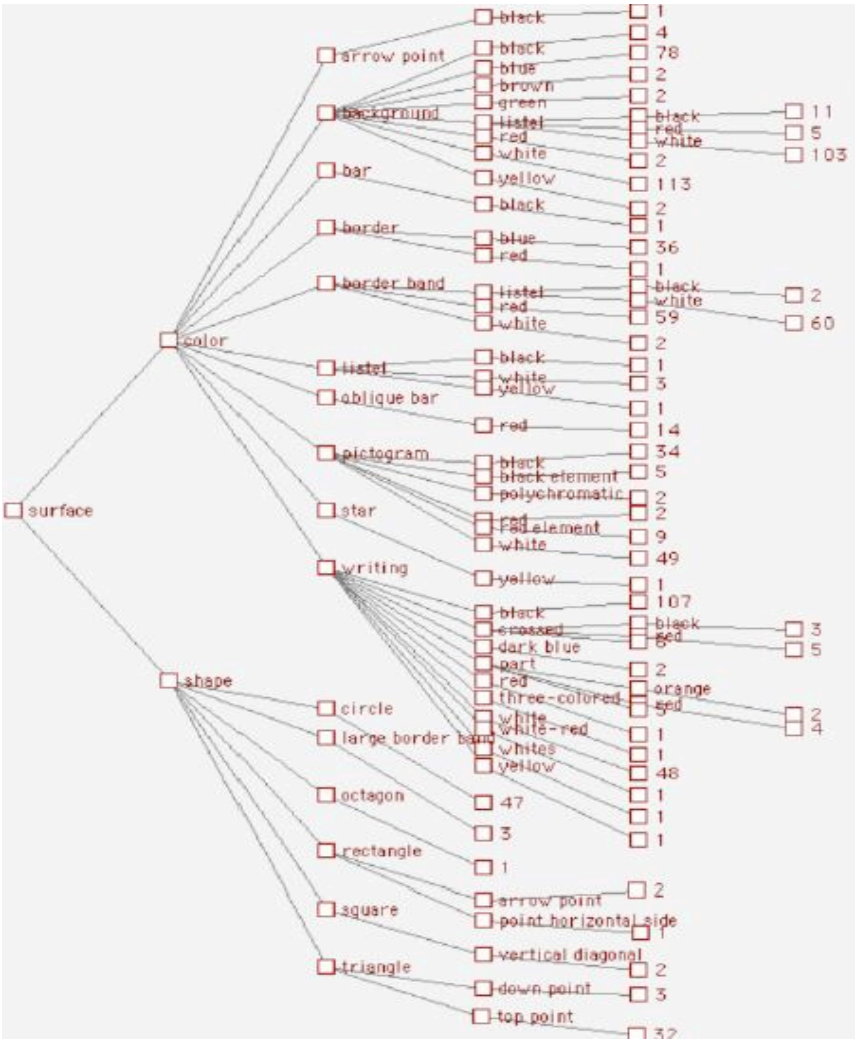


Figure 3. Ontology of the surface properties of the whole set of French Road Signs.

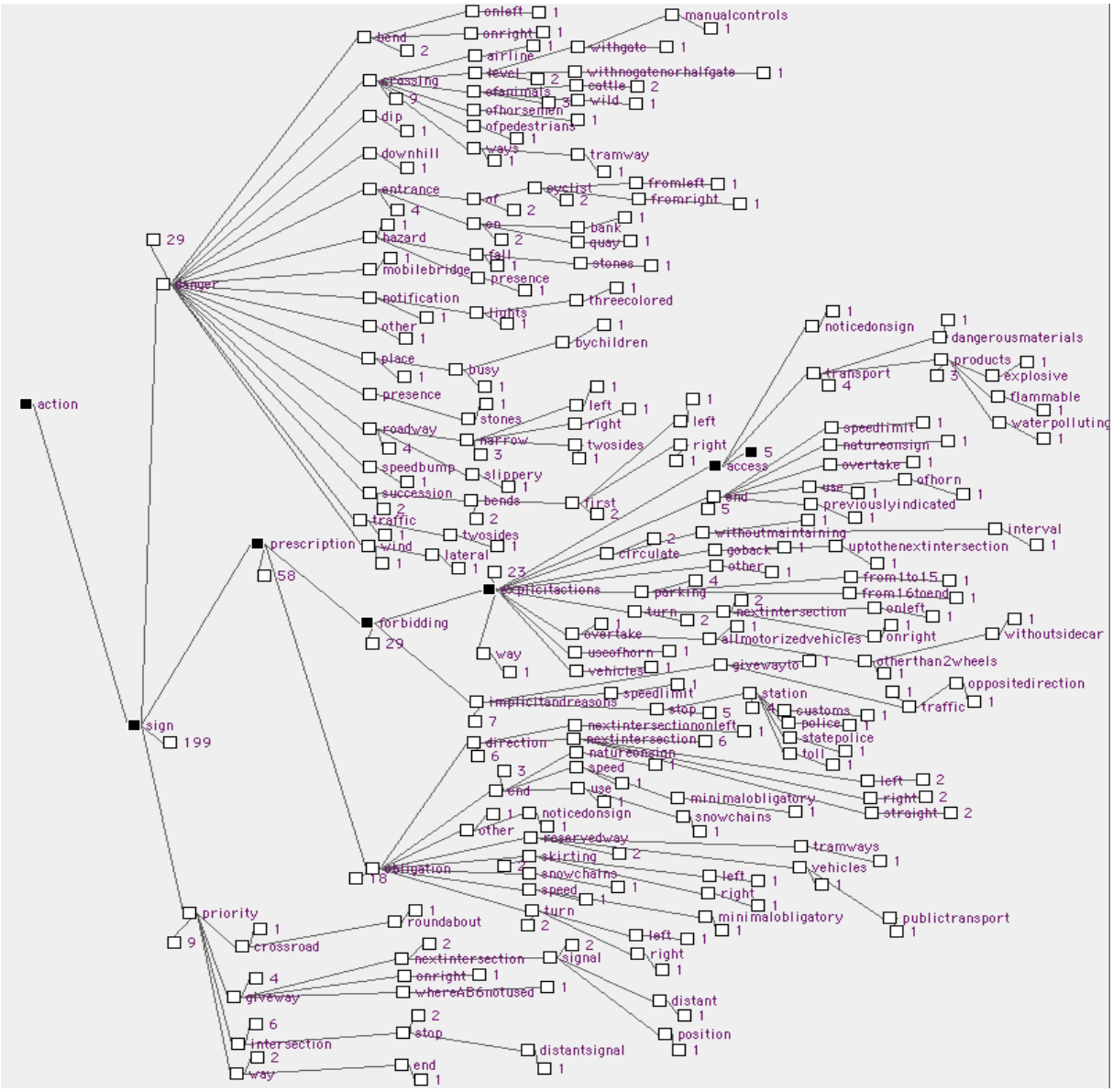


Figure 4. Ontology of the required actions when facing the whole set of French Road Signs.

Whereas the surface properties taxonomy is quite simple, the tree presenting the ontology of actions is more complicated. We can see also that the surface description doesn't match the action description, either for shape or color. This means that to a same class of actions corresponds different shape or different colors. The road signalization system appears to be a complex system that is not fully coherent since surface properties often match partially with the corresponding actions properties.

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 overtake another car*": does it means that a motorcycle or a van can do it?

WHAT DOES A COMPARISON BETWEEN EXPERT AND NOVICE DRIVERS TEACH US?

We reasoned that the first step to study the gap between expected and observed behavior would be comparing expert and novice drivers about the understanding of road signs. Efficiently, the latter are well known to be more implied in road crashes than the former (the 15-24 years represent 40 % of the total amount of persons killed in 2004). It is also known that experimented drivers fail when asked to give the meaning of road signs. Contrary, we can expect that because they have learn the highway code more recently, novices should have better scores on such a task.

We then ran an experiment where novices and experts (123 participants) were showing 40 road signs in context or out of context. We asked them for each sign, what does it mean and what is the action to perform in such a situation. Participants were ranked given the number of year of practice: 21 have no driving 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. Table 1 shows the results of this experiment.

	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?"

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: the more one drives, the 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.

The interesting result is that the more you drive, the more you lose the theoretical knowledge about road signs, although practical knowledge remains. With the acquisition of expertise, the gap between procedures and practices increases. In other words, with the acquisition of expertise, road signs lose their codification function to become one of the elements that entail the process of contextualizing a driving situation.

Whereas the Highway Code prescribes codified behaviors, drivers behave according to a practical experience of driving. They behave depending on their current task, the environmental context, and their knowledge about similar situations.

Road signs interpretation depends on contextualized inferences. Drivers 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 et al., 1971). Thus, there are 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. The information given by a road sign is then context-dependent.

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 & al., 1971).

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 than 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.

Then, if we want to model the behavior of road users, we have to take into account not only the road signs but also much contextual information.

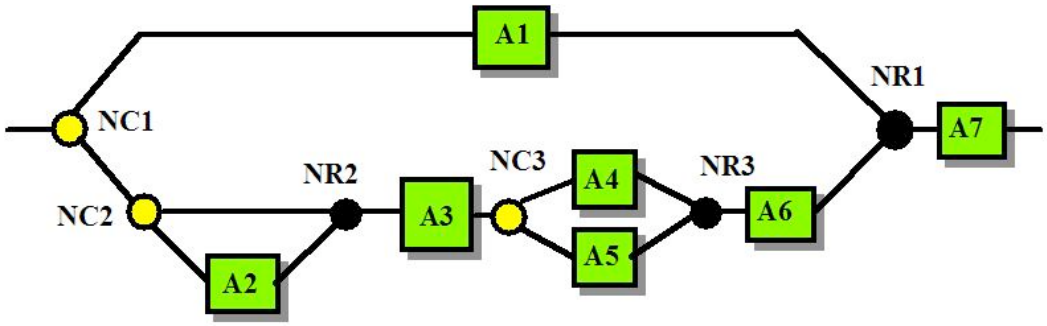
A CONTEXT-BASED FORMALISM

Contextual graphs (Brézillon, 2003, 2005) allow a representation of practices based on context. They are oriented graphs, acyclic and with a general structure in spindles. A contextual graph is made of nodes and arcs and, more particularly, actions (noted A), contextual nodes (NC), recombination nodes (NR) and groups of parallel actions (not considered in this paper).

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 (the instantiated contextual elements on the path) for choosing an action sequence.

We show the theoretical contextual graph that could be built from the road sign "*Dangerous bend on right*" on Figure 5.



NC1	Do I see the road sign?
NC2	Yes. Do I recognize it?
NC3	What about the distance to obstacle?
A1	No, then I keep the same behavior.
A2	No, then I have to identify it from the situation.
A3	I have to find the situation corresponding to the road sign.
A4	Obstacle is close, then I focus on it immediately.
A5	Obstacle is far, I postpone first other actions.
A6	I reduce my speed in order to …
A7	… Turn right.

Figure 5. Contextual graphs associated to the road sign  "*Dangerous bend on right*" presenting the set of possible actions.

Contextual Graphs make it possible to describe practices (Figure 3) as well as the strict application of the prescribed procedure of the Highway Code (the black way in the Contextual Graph displayed in Figure 6).

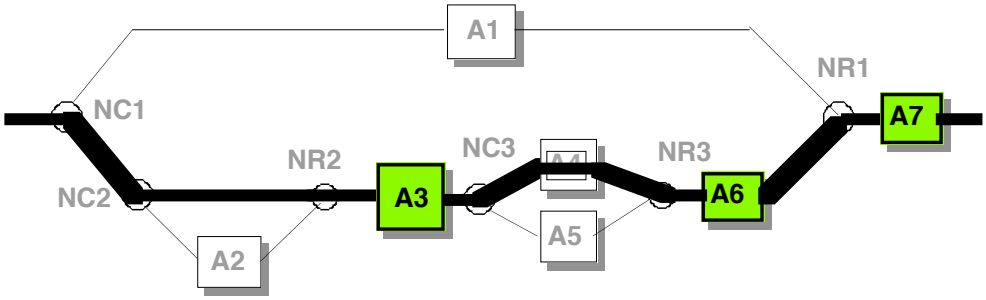


Figure 6. Description of the prescribed procedure derived from the Highway Code for the road sign "*Dangerous bend on right*".

Figure 5 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 1), 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.

CONCLUSION

We claim in this contribution that some transgressions of the highway Code (not the voluntary ones) are attributable, not to a congenital lack of respect to laws, but to an inherent ambiguity in the system due to not only the iconic format but also to the contextual nature of the human functioning (Tijus, 2001). We have show that road signs, because an iconic message cannot be exhaustive, are ambiguous at an individual level (they do not systematically provide clearly the agent, action and object concerned by the message) and at the general level of their generic system (surfaces properties and actions do not match). We reported data about the use of the system: with the acquisition of expertise, drivers lose the legislated meaning of road signs but stay capable of giving the correct action to do, especially when the road sign is presented in context. We have proposed, then, a formalism based on context, which is able to catch the contextual clues used by drivers when they have to make a decision about their behavior, facing a given road sign. We think that contextual graphs can be as helpful in psychology of driving as is the determination of the space base of a given problem in the domain of problem solving (Newell & Simon, 1972).

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