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## Awareness and behaviour of road tunnel users: what headway has been made since the 2000s?

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### Abstract

The safety of a road tunnel depends not only on its design and operation, but also on the users' knowledge of the tunnel. Therefore, in France, the Centre for Tunnel Studies (CETU) conducted in 2004 a qualitative survey focused on tunnel users' knowledge of the tunnel and its equipment. Following this survey, several actions were implemented and in order to measure their impact, a similar survey was conducted in 2015. It highlighted an improved knowledge of existing safety equipment especially of the blue marker lights on side walls designed to help drivers maintain an appropriate safety distance.

In order to check this knowledge of the blue marker lights, CETU designed a regulatory road sign and tested its installation at the entrance to the Foix tunnel in the Occitanie region. At the end of 2016, approximately 600 users were questioned on their understanding of the road sign in a survey, which was conducted via Internet and via a questionnaire hand-delivered to participants' homes.

**Keywords:** Tunnel; safety; road sign; behaviour; user acceptance; user understanding.

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## Nomenclature

CEREMA	Centre for studies and expertise on risks, environment, mobility, and urban and country planning
CETU	Centre for tunnel studies
IFSTTAR	French institute of science and technology for transport, development and networks

## 1. Introduction

Tunnel safety has been the subject of considerable regulatory amendments in recent years. These changes primarily relate to technical aspects and the organisational dimension of safety management. Feedback from events in tunnels has moreover highlighted the crucial importance of paying sufficient attention to user behaviour in the design and operation of road tunnels.

These concerns, directly related to operational safety, are the core of the work carried out as part of a CETU research project. The aims of this project may be summarised as follows: improving understanding of these human and organisational factors and acquiring information which can be used to optimise infrastructure design and introduce the most appropriate measures for tunnel operation and for users.

This article firstly presents the results of two large-scale surveys carried out in 2004 and 2015 on users' knowledge and understanding of regulatory equipment and road tunnel safety. During these 11 years between the 2 surveys, several actions targeting driver training and information were set. This period was considered necessary to ensure that users have appropriated these actions. Secondly, it describes the results of a survey designed to evaluate users' understanding of a new information sign on devices available to help them maintain safety distances. This survey was part of an experiment to see if the sign was suitable for inclusion in the Highway Code. As well as comparing the methodology of these different survey types, cross-referencing the data and results helps to consolidate our understanding of human factors and in particular, the advantage and effectiveness of informing users about the safety equipment at their disposal.

## 2. The ACTEURS project

Aware of the essential role of users, an applied research project named ACTEURS began in 2003, which focussed on the behaviour of tunnel users under normal driving conditions and in a crisis situation.

Initiated by the alpine motorway companies, involving three motorway concession companies operating 11 tunnels in the Rhone Alps region, the aim of the project was to gain a better understanding of the interaction between users and tunnels, model typical user behaviour in normal driving conditions and crisis situations and use this information to propose safety improvements.

### 2.1. The large-scale survey

The ACTEURS project included a qualitative survey carried out in 2004, in which 620 tunnel users were interviewed. This survey provided information about users' knowledge of road tunnel safety and how they understood and used this infrastructure. For each tunnel, the questionnaires focussed on users' knowledge of the tunnel and its equipment, their knowledge and understanding of safe driving behaviour in tunnels and the behaviour they would spontaneously adopt in the event of an accident or fire alert in the tunnel.

The results of this survey led to several actions targeting driver training and information:

- Several public communication and information campaigns on the specific nature of driving in tunnels were conducted by tunnel operators;
- Since 2006, issues around the specific nature of driving in tunnels have been included in driver training and specific questions asked in the theory test;
- Training for professional drivers includes a module on driving in tunnels as part of both initial and continuing training.

Other measures have been taken, affecting both the infrastructure itself and organisational aspects of tunnel operation, in order to make safety facilities more comprehensible to users. For example, a green arch has been painted on the side walls to indicate the location of emergency exits and lighting systems have been added, enabling users to identify and locate these safety facilities in normal traffic situations.

To measure the effects of these actions on awareness and behaviour, a new survey was carried out in 2015. Results concerning the behaviour adopted in crisis situations are not considered in this paper.

## 2.2. Survey methodology

The two surveys were carried out over equivalent periods of approximately three weeks in the same places, 5 motorway rest areas belonging to the three alpine motorway operators, by a service provider recruited as part of a public procurement contract. These rest areas are situated near 4 tunnels, two of which are cross-border tunnels: the Mont-Blanc tunnel and the Fréjus tunnel. Figure 1 indicates the location of the survey sites.

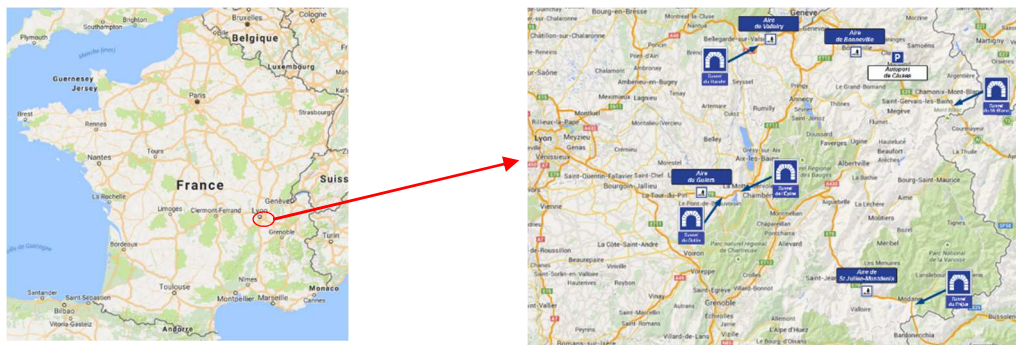


Fig. 1 location of survey sites (source Google)

The 2015 questionnaire was more or less identical to the one used in 2004, but with additional questions on training received in relation to the actions implemented between the two surveys. The questionnaire included closed multiple choice questions and open questions. In total, each user was asked some fifty open questions and multiple choice questions by a professional trilingual (French, English, Italian) surveyor. Although the questionnaires took 20 to 30 minutes to complete, the two surveyors did not report any particular difficulty carrying out interviews.

Concerning equipment, questions were added about users' understanding of the C111 tunnel sign and the blue marker lights designed to help maintain safety distances, as these safety devices did not exist in 2004. A question on awareness of emergency exit signs was also added.

## 2.3. Comparison of 2004 and 2015 results

The comparisons made in the present document are considered significant in view of a confidence index of 95%. This percentage is that which is currently used for this type of statistical analysis. The margin of error is calculated by taking into account two main factors: the sample size and the confidence level.

To compare the two percentages, the significance of the order of magnitude needs to be analysed. To do so, online software (<http://www.mediametrie.fr/calculettes-mediamedetrie.php>) was used to determine if the comparison between the two percentages was actually possible.

For example, 38% of the users questioned in 2004 cited emergency exits as safety facilities as opposed to 55% in 2015. The software confirms that this difference is significant for a sample of 600 users with a confidence level of 95%. If only 43% of users had cited emergency exits in 2015, then this difference would not have been considered significant.

For the comparisons in present report, the significance of the percentage differences will therefore be calculated.

### 2.3.1. Respondent profile

To ensure good comparison of the results of both surveys, the service provider was required to select a sample of users comparable with that of 2004, with about 50% of respondents being heavy goods vehicle (HGV) drivers. Table 1 gives details of the samples of the two surveys.

Table 1. Number of respondents.

Tunnel	2004 (HGV)	2015 (HGV)
Mont-Blanc	151 (104)	147 (100)
Fréjus	154 (137)	154 (136)
Vuache	164 (45)	171 (54)
Dullin / Épine	151 (27)	151 (27)
TOTAL	620 (313)	623 (317)

Travel was mostly work related (63% in 2004 and 68% in 2015) for the predominantly regular users (60% in 2015 compared with 55% in 2004) especially those using a trans-alpine tunnel (Mont-Blanc and Fréjus), who represented two thirds of the users interviewed in each of the two surveys.

Table 2 shows the main nationalities of the drivers interviewed. The vehicle/nationality correlation, only possible in 2015, shows that most of the car drivers interviewed were French, Italian, Swiss or British.

The other nationalities were mainly HGV drivers. Although totally absent from the 2004 survey, HGV drivers from Eastern European countries (Romania, Poland, Bulgaria, Hungary, Latvia, Lithuania, Slovakia and Slovenia) now make up a non-negligible part of the sample (15%). This figure can be explained by the accession of these countries to the European Union between 2004 and 2007, having abolished customs duties with the other Member States (free movement of goods within the Community has also been considerably reinforced by the new legislative framework of 2008, Regulation (EC) No 765/2008 of the European Parliament and of the Council).

Table 2. Nationality of respondents (cited by at least 1% of respondents).

Nationality	2004	2015
French	73%	49%
Italian	12%	14%
Romanian	0%	6%
Swiss	2%	6%
British	4%	3%
Bulgarian	0%	2%
Belgian	4%	2%
Polish	0%	2%
Greek	0%	2%
German	1%	1%
Spanish	0%	1%
Hungarian	0%	1%
Latvian	0%	1%
Lithuanian	0%	1%
Dutch	0%	1%
Slovak	0%	1%
Slovenian	0%	1%

### 2.3.2. Respondents' feelings when using a tunnel

In 2004, one in five people thought using a tunnel was a demanding experience. In 2015, tunnel use was commonplace and nearly 9 out of 10 people were indifferent to it. As in 2004, reasons given for finding tunnel use demanding were mainly related to stress and the narrowness of the tunnel. The length of the tunnel (Fréjus and Mont-Blanc) was not given as a reason by users, unlike the 2004 survey.

### 2.3.3. Knowledge of tunnel equipment

Users were asked about the equipment available in the tunnel they had used. Compared with 2004, they knew more about the equipment provided in road tunnels. Nearly 55% of users spontaneously stated that there were emergency exits in the tunnel they had used. Compared with 39% of users in 2004, this is a statistically significant difference. As these were spontaneous responses and not presented to the user in a list or as a yes/no question, it would appear that users had really taken on board the fact that this equipment was present in the tunnels. In 2004, 12% of users mentioned shelters compared with less than 5% in 2015. As users might have thought of shelters as emergency exits, it was necessary to compare (shelter + emergency exit) responses between 2004 and 2015. In 2004, 311 users mentioned shelters or emergency exits, i.e. 50% of users. In 2015, 361 users mentioned shelters or emergency exits, i.e. 58% of users. The difference between 2004 and 2015 is statistically significant.

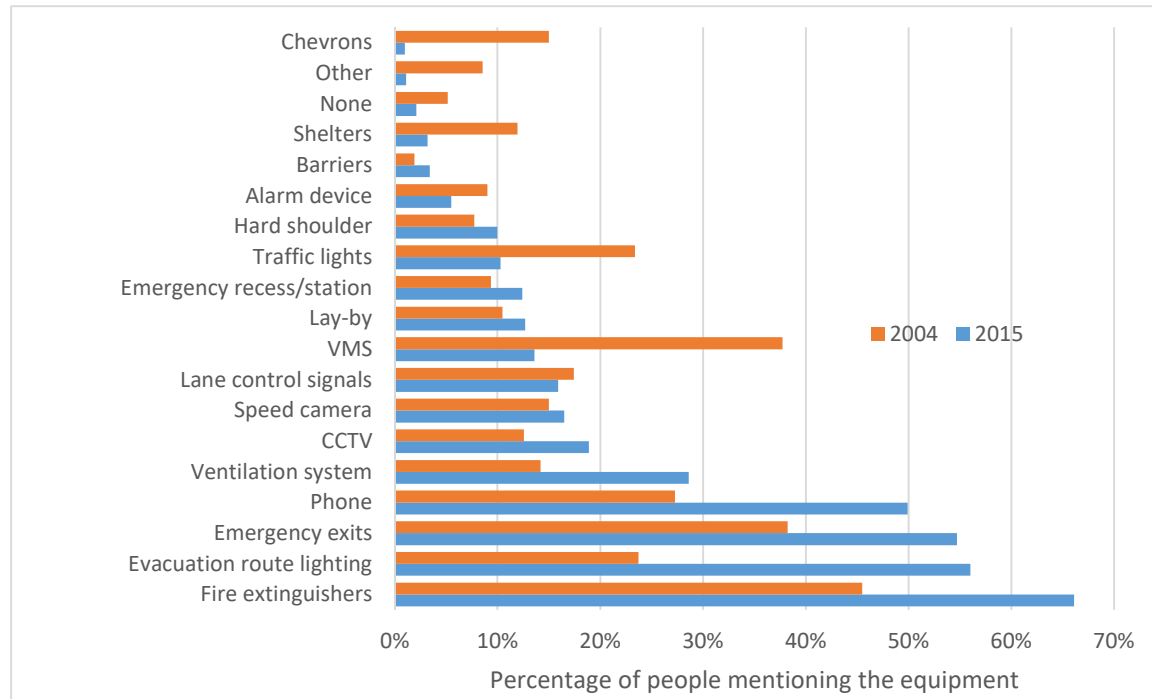


Fig. 2 tunnel equipment mentioned by users

The main safety equipment available for users was mentioned by more than 50% of users.

- Telephones were mentioned by 50% of users, compared with 27% in 2004;
- Fire extinguishers were mentioned by 65 % of users, compared with 45 % in 2004;
- Evacuation route lighting was mentioned by 56% of users, compared with 24% in 2004.

Users were also more aware of CCTV cameras and ventilation systems. These differences are statistically significant. Traffic lights (red lights) and variable message signs were, on the other hand, mentioned less than in 2004. There is really no explanation in the case of traffic lights, which are present at each tunnel entrance but turned off.

Only 13% of users mentioned variable message signs in 2015, compared with 37% in 2004. This difference is statistically significant. Variable message signs are now very numerous on the motorway network, it is therefore possible that users no longer perceive them as specific tunnel safety equipment. Furthermore, variable message signs are activated continually in the open air and only activated in tunnels when there is an incident. They are consequently less visible. Where other equipment is concerned, the differences are not significant.

Users were then questioned about their awareness of the existence of emergency exits. In 2004, 84% of users knew that emergency exits were provided in the tunnel they had just gone through. In 2015 this percentage was 99%. Furthermore, over 90% of respondents thought they would be safe using an emergency exit. The increase since 2004 (+ 20%) shows that users are more confident about the safety of road tunnels.

#### 2.3.4. Knowledge of traffic regulations

Concerning the speed limits in tunnels, 93% of users knew they existed in 2004, compared with over 99% in 2015. The difference is significant. More people knew about the speed limit in the cross-border tunnels than in the other motorway tunnels, in which it was often underestimated:

- In the Vuache tunnel, over 20% of users said the speed limit was 70 km/h, although it is actually 90 km/h;
- In the Dullin and Épine tunnels 20% of users said 90 km/h, although the speed limit is actually 110 km/h.

In 2015, 96% of users thought it was easy to maintain this speed limit, compared with 86% in 2004.

In 2004, users thought the purpose of this speed limit was to prevent collisions and to a lesser extent to reduce stopping distances (these objectives going together). In 2015, users mainly associated this speed limit with the reduction of stopping distances. This change can be explained by road safety campaigns.

Concerning the safety distance, 84% of car drivers in 2004 knew there was a minimum distance they had to maintain between their vehicle and the one in front (this mandatory distance is double for heavy vehicles). In 2015, it was 89%. Although there was an increase, the difference is not significant in view of the sample as a whole. On the other hand, the increase is significant for users (cars and HGVs) in the Dullin and Épine tunnels: 91 % in 2015, compared with 74 % in 2004.

As in 2004, regular users knew more about safe inter-vehicle distances in tunnels than occasional users. Almost 99% of HGV drivers knew of the existence of a specific safety distance in tunnels; this percentage was similar in 2004.

In 2015, nearly 97% of cross-border tunnel users knew what the safety distance was. In particular, more users of the Mont-Blanc tunnel knew what the minimum safety distance was in 2015, compared with 2004. In 2004, 18% of users underestimated this minimum distance. The difference compared with 2015 is significant. For users of the Fréjus tunnel, there was no significant change.

For the motorway tunnels:

- 17% of users (almost all of which were car drivers) of the Vuache tunnel underestimated this distance (35% in 2004). This correlates to the underestimation of the speed limit. The difference is significant;
- 35% of users (almost all of which were car drivers) of the Dullin and Épine tunnels underestimated this distance (44% in 2004). The difference is not significant.

In conclusion, we did not observe any significant change in the knowledge of cross-border tunnel users. Over 97% of them knew the distance they had to maintain. On the other hand, other motorway tunnel users' awareness of the safety distance had increased. The percentage of motorway tunnel users knowing the exact distance increased from 15% in 2004 to 27% in 2015. However, there is room for improvement for car drivers using motorway tunnels.

In 2015, 85% of users (68% in 2004) thought it was easy to maintain the mandatory safety distance. After 2004, blue marker lights were installed in tunnels as shown in figure 3, to help users calculate the safe distance from the vehicle in front (2 blue lights for cars and 3 blue lights for HGVs). The disparity in speeds and heavy traffic were the reasons given by those who thought it was difficult to maintain this safety distance.



Fig. 3 blue marker lights in a tunnel (photo CETU)

A specific question on blue marker lights was therefore added to the 2015 questionnaire. 93% of users said they had seen the blue marker lights and 89% of users knew that the blue lights were to help them maintain the safety distance.

### 2.3.5. Results

Compared with 2004, the results of the 2015 survey show that users were more comfortable with travelling through a tunnel. They had more awareness of the safety equipment and more confidence in it. They also had more knowledge of the regulations regarding safety distances and speed limits in tunnels.

## 3. Blue marker lights

A particularly significant result of the 2015 survey is the fact that so many users knew about the existence of blue marker lights for estimating the safety distance in the tunnel. The blue marker lights are interspersed with yellow lights on the side wall to indicate the safety distance at the speed limit. Yellow lights are tunnel safety equipment indicating the way to the emergency exits, in a fire for example. Although the high number of users saying they knew what the lights were for can be explained by the location of the survey in the Rhone Alps region, it is still surprising. The numerous public information campaigns run by the tunnel operators in the Rhone Alps region may perhaps explain this result.

As the existence of the blue marker lights was indicated by safety messages displayed on variable message signs and on assorted, non-regulatory signs on the approaches to tunnels fitted with this equipment, CETU wanted to standardise practice and pilot a single sign so that this would become the regulatory reference. To prevent a location bias, a tunnel in the Occitanie region of south west France was chosen for an experiment.

### 3.1. The context

At the end of 2016, users of the Foix tunnel were interviewed about their knowledge of the new sign that had been installed at the entrance to this tunnel two months earlier, as shown in figure 4.

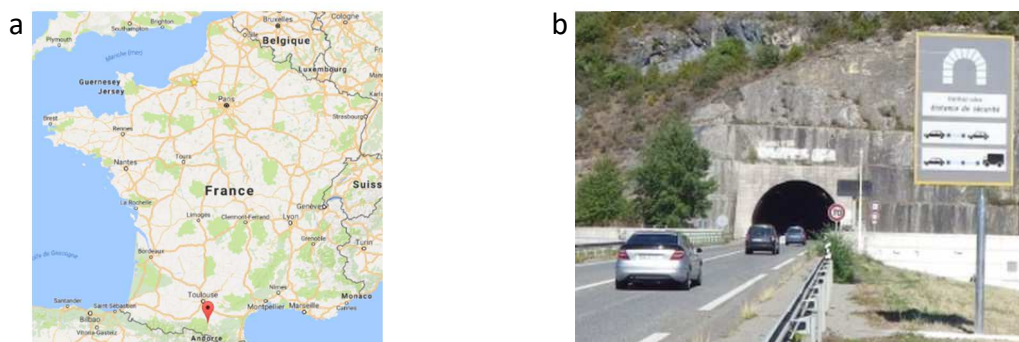


Fig. 4 (a) location of the Foix tunnel (source Google); (b) piloted sign installed at the tunnel entrance (photo CETU)

The survey was carried out using two different means of communication:

- Via the internet: the questionnaire, available in three languages (French, English, Spanish), was uploaded onto the CETU, tunnel operator and Ariège Prefecture websites for 3 months;
- By letter: a paper version of the questionnaire written in French and a stamped addressed envelope, were hand-delivered by the postman, under a mandate from the Ministry, to a panel of 2500 households selected by age (in proportion to the department's age pyramid) and their place of residence, located on the routes that included the Foix tunnel.

### 3.2. The respondent profile

Of the 390 paper questionnaires received (15% return rate) and 296 questionnaires completed on the internet, 520 were deemed usable (320 paper and 200 electronic). 195 were completed by women and 323 by men (2 people did not indicate their sex) and only 2 HGV drivers took part in the survey. Respondents were mainly over 40: 41% aged between 41 and 60, 36% over 60.

As questions on tunnel driving were included in the driving test in 2006, people were asked what year they obtained their driving licence. 81% of respondents had obtained their licence before this date.



Of the 520 respondents, 412 had gone through the tunnel in the 15 days before filling in the questionnaire. 52% of them were frequent users (one or more times per month), 35% very frequent (one or more times per week) and the others less frequent.

### 3.3. Visibility and function of blue marker lights

90% of people who had used the tunnel said they had seen the marker lights inside the tunnel. This figure is constant according to frequency of tunnel use, type of vehicle driven and year of acquiring a driving licence. Concerning the colour of these lights, blue (stated by 76% of respondents) and yellow (46%) were the colours most commonly mentioned. A major difference between the internet version and the paper version of the questionnaire concerns the visibility of the sign. In the first instance, the sign appears temporarily between two questions situated at the beginning. In the second, the sign is visible the whole time. The sign is shown in colour in both cases, i.e. with blue lights. One might ask if the type of questionnaire had any influence on the responses received. However, the percentage of people who responded “blue” was the same on both paper and internet versions: about 230 people in total. In fact, 142 mentioned both blue and yellow as the colours of the lights in the tunnel, although yellow is not shown on the sign.

Users were then asked what these lights were for: the yellow lights are direction indicators for users evacuating on foot; the blue lights show the safety distance between two vehicles travelling at the speed limit in the tunnel.

- 25% of respondents did not know;
- 43% cited the safety distance, 93% of them said they were blue;
- 21% cited route marking (or lights) and of them, 43% said they were yellow;
- 3% cited both responses and of them, 58% said there were blue and yellow lights.

Thus, compared with the 2015 survey, a similar proportion of people had seen the lights, but their function was a different story. This seems to confirm the influence of public information campaigns in the Rhone Alps region.

### 3.4. Knowledge of the safety distance

As with the large-scale study, nearly all respondents knew of the existence of a safety distance to be maintained in the tunnel (95% for the Foix tunnel, compared with 94% for the 2015 Rhone Alps survey). In the Foix tunnel, this distance for cars is the distance travelled in 2 seconds, i.e. 39 meters for the 70 km/h speed limit. There is no specific sign for this rule of the highway code. For HGVs, this distance is regulated and set at 100 meters. A B17 sign is present on the approach to the tunnel portal.

20% of people who knew of the existence of a safety distance to be maintained said they did not know what it was. Only 9% estimated it correctly (give or take 5 meters for the 70 km/h speed limit). 41% overestimated it and 31% underestimated it, sometimes by a large amount: one third of them thought it was less than 10 meters.

### 3.5. Understanding of the sign

71% of respondents said they had seen the sign at the entrance to the tunnel (see figure 5). Although it is an information sign, 45% thought it was a recommendation and 38% thought it was mandatory.

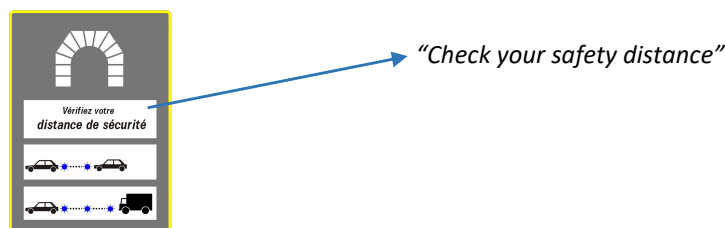


Fig. 5 piloted sign

The most eye-catching part of the sign is generally the white arch. The blue marker lights were also well perceived, especially by young people and people who had obtained their driving licences more recently.

The vast majority of respondents (85%) understood that the sign indicates that you have to check your safety distance in a tunnel and nearly 70% understood that you could do this with the aid of a fixed lighting system.



### 3.6. Behaviour adopted

The 368 people who saw the sign were asked how this changed their behaviour when they went through the tunnel: 228 said they had changed their attitude, and 194 of these had understood that the sign meant “check your safety distance in a tunnel”. The behaviours adopted are shown in the graph in figure 6. In blue, the number of people who gave just one answer, in yellow the number of people who gave more than one answer (for example, 151 people slowed down, while 63 only answered “I slowed down” and 88 also located the blue marker lights or checked their rear-view mirror).

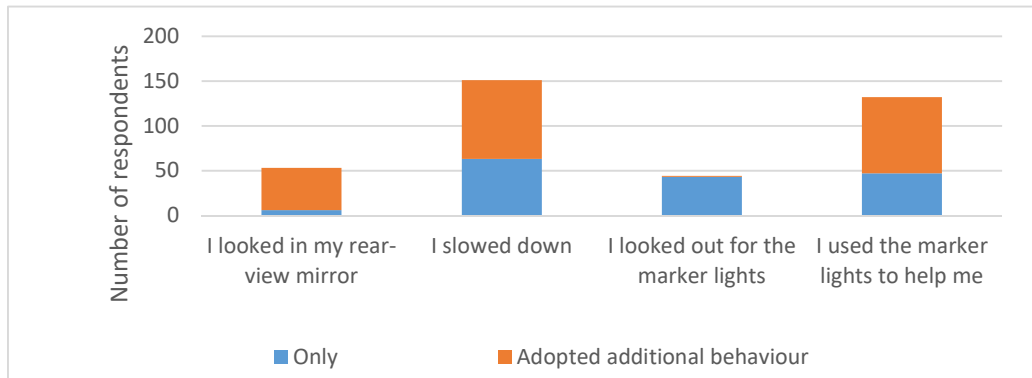


Fig. 6 behaviour adopted after seeing the sign

Overall, 97% of respondents said they had changed their behaviour. In fact, apart from a small number who had only looked in their rear-view mirror (6 people), the vast majority thought they had slowed down to increase their distance from the vehicle in front, possibly with the aid of the blue marker lights.

79% of those who said they had not changed their behaviour claimed this was because they were already maintaining the safety distance. Yet, over half of them either did not know what this distance was or underestimated it.

Those who claimed to have modified their attitude after seeing the sign then explained how they had estimated the safety distance to be maintained in the tunnel: 70% said they used the blue and yellow lights. When they were asked how many blue marker lights they left between their vehicle and the one in front, the majority said two (52%). 12% said less than two and 25% more than two (12% did not know or did not answer).

Finally, users were asked if they had known these lights were to help them maintain the safety distance between two vehicles before they saw the sign. 55% of respondents said they had not known what they were for before they saw the sign (even so, 71% of them knew there was a safety distance).

Of these, 56% of those who had seen the sign claimed to have modified their attitude when they saw it, and a third of them had located and/or used the blue marker lights to change their position in relation to the vehicle in front.

### 3.7. Results

With a 95% confidence interval, we can estimate that between 51% and 69% of the proportion of people who responded to the questionnaire had not known what the blue marker lights were for before seeing the sign. Of these, 57% correctly interpreted the sign as an aid for maintaining the safety distance with the aid of fixed lights (compared with 83% of those who already knew the purpose of the blue marker lights). Overall, the sign was well perceived by 71% of respondents.

As for the influence the sign might have had on users' behaviour, it is quite considerable, as 61% of people who had seen the sign claimed to have modified their attitude and 77% of those who claimed not to have changed anything said they were already maintaining the safety distances.

#### 4. Conclusion

By conducting two interview surveys 11 years apart, in an identical situation, it has been possible to measure how road users' knowledge of road tunnel safety has changed. For each technical device implemented for users, it was possible to determine whether it was correctly understood or if it should be modified to ensure better understanding. In this context, the interview survey turned out to be a useful tool for conveying road users' experience and knowledge of road tunnel safety. Despite the length of the questionnaire (30 minutes), interviews were successfully carried out with users.

During the trial of a sign informing users of the meaning of blue marker lights giving guidance on safety distances in tunnels, two other types of survey were adopted: an internet survey and a hand-delivered postal survey. The number of usable questionnaires compared with the number of questionnaires received demonstrates the limits of an impersonal approach compared with an interview type survey. In view of the response rate, these tools are nevertheless suitable when geographical and organisational conditions are not compatible with an interview type survey. But this presupposes few open questions and consequently a more Cartesian approach to human behaviour.

The results of both surveys can be analysed and compared with regard to compliance with safety distances and in particular the awareness and meaning of blue marker lights. Both surveys show that users had noticed the blue marker lights when going through the tunnel. Nevertheless, although 86% of users questioned in the large-scale survey of 2015 claimed to know the function of this specific equipment, only 45% knew this function in the survey related to the piloting of the new sign. This confirms the influence of both public information campaigns initiated by the tunnel operators in the Rhone Alps region and specific signage, either variable message signs or roadside signs, even though they are heterogeneous and non-regulatory at present.

Knowledge of human behaviour is therefore very important for the validation of regulatory safety equipment that has been implemented or for evaluating the piloting of new equipment. For the case presented here, which involved the piloting of an information sign on blue marker lights, subsequent introduction of this sign into the highway code will enable this information to reach a wider public through inclusion in the driving test and standardisation of the sign across France.

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