Road-tunnel fires: Risk perception and management strategies among users

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Abstract

The present study was aimed at investigating road users' perceptions and behaviors in case of a fire in a tunnel. It is grounded on the idea that in order to effectively prevent accidents and fires in tunnels, it may be useful to take tunnel users' beliefs, representations, and coping strategies into account [Kouabenan, D.R., 1998. Beliefs and the perception of risks and accidents. Risk Analysis, an International Journal 18, 243–252; Kouabenan, D.R., 2001. Management de la sécurité: rôle des croyances et des perceptions. In : Lévy-Léboyer, C., Huteau, M., Louche, C., Rolland, J.P. (Eds.), RH: Les apports de la psychologie du travail. Les Editions d'Organisation, Paris, pp. 453–474; Kouabenan, D.R., Cadet, B., 2005. Risk evaluation and accident analysis. Advances in Psychology Research 36, 61–80; Kouabenan, D.R., Dubois, M., Scarnato, F., De Gaudemaris, R., Mallaret, M.R., 2007. Methicillin-Resistant *Staphylococcus Aureus* Risk Perception by Healthcare Personnel in a Public Hospital. Social Behavior and Personality, 35, 1] One hundred and fifty-one road users (firemen, truck drivers, regular drivers, and driving-school students) filled out a questionnaire measuring their perceptions of risks and control in road tunnels, their awareness of safety and rescue devices, their level of anxiety, and their behavioral intentions in the event of a fire in a road tunnel. The results indicated a relationship between fire-risk perception, awareness of rescue and safety devices, and road-tunnel experience; a tendency toward comparative optimism (CO); an effect of perceived control on optimism; and a relationship between CO and awareness of safety devices. A significant interaction was found between tunnel users' anxiety level and their perceived control over the situation. The evacuation behaviors and coping strategies reported by the participants were far from reflecting the expected behaviors. Recommendations for a long-term prevention policy bearing jointly on beliefs, behaviors, improved information and warning systems are suggested.
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1. Research objectives and issue

Road tunnels constitute essential public-works projects, from both a practical and an economic standpoint, because they limit the length of trips and thus reduce transportation time and costs. However, according to a brochure from the French Ministry of the Interior and Ministry of Transpor-tation, Equipment, and Housing (Ministère de l'intérieur, Ministère de l'équipement des transports et du logement, 2000), catastrophic tunnel fires in the last seven years (Mont Blanc tunnel between France and Italy in 1999 with 39 deaths, Tauern tunnel in Austria in 1999 with 12 deaths and 60 persons injured, Saint Gothard tunnel between Switzerland and Italy in 2001 with 11 deaths, etc.) have led the public as well as European and French authorities to be more concerned with the safety of these structures and of the people who use them. Tunnels are particularly difficult to access during rescue operations. In crowded traffic conditions, it is hard for rescue vehicles to get

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around obstacles, and it is often impossible to get inside the tunnel to reach the scene of the fire. Furthermore, the enclosed nature of tunnel structures leads to rapid temperature increases during a fire and causes problems for ventilation and exhaust of fumes (see Benelux report on tunnel fire simulation; Boer, 2002). Today, more and more studies are focusing on improving smoke exhaust in the event of a fire and on learning more about tunnel users' behavior in such situations. For publications on this topic, see for example the UPTUN project report (Papaioannou and Georgiou, 2003), the ACTEURS project (Noizet et al., 2003), the Benelux fire study (Boer, 2002) and the present study, financed by the Rhône-Alpes Region of France. As a result of these studies, equipment upgrades have been made in order to improve incident detection in tunnels and enable users to quickly get to safety.

However, while technical progress in the area of tunnel safety is real, a mastery of the risks inherent in such structures also involves taking into account the risk-coping behavior of people, especially their perception of risks (Kouabenan, 1998, 1999, 2000; Kouabenan et al., 2001). Indeed, when a fire or accident happens in a road tunnel, users do not always evacuate according to the instructions they are given. For example, during the Mont Blanc catastrophe, 27 people among the 39 who died did not leave their cars, and two others who did leave their cars died in another vehicle where they had taken refuge (Brocquet, 2002). In the tunnel surveillance videos that we viewed, it was common to see users in fire situations leaving their vehicle and then returning to it to wait for rescue or to wait for several long minutes before evacuating the tunnel. Such attitudes are perhaps due to a failure to perceive the risks involved, an overestimation of intervention means, or a overly high assessment of one's ability to cope with risks.

Two difficulties related to informing the public before and during the breakout of a fire add to the problem. Firstly, given the diversity of tunnels (i.e., two-way vs. one-way, short vs. long, old vs. more recently built), users' awareness of available safety measures for themselves and for other tunnel users seems to be poor or incomplete. This type of information must therefore be provided on a case-by-case basis. Safety devices and measures for French tunnels vary according to the size of the tunnel, the type of tunnel, and the technical possibilities, a situation which makes it difficult to inform the public in advance about all existing safety provisions. Secondly, from the technical standpoint, information about a fire breaking out in a tunnel cannot be communicated to all drivers in a tunnel at the same time, so evacuation of a tunnel can only be accomplished with effective collaboration, not only among the drivers in the tunnel but also between the safety operators themselves and whatever users they are able to contact. In this sense, users who are told there is the fire and are informed of what to do become intermediaries for spreading this information, and as such, they become an integral part of the rescue system.

This article reports a study conducted within a broader research project financed by the Rhône-Alpes Region of France concerning fire prevention in road tunnels. Research teams from several different disciplines are involved. The study presented here deals solely with the psychological aspects of the project. In particular, we attempted to understand risk-management strategies implemented by tunnel users during fires by examining their representations of fire risk, their knowledge of safety and intervention devices, and their evacuation-related behaviors. The study is based on the idea that effective long-term prevention of accidents and fires in tunnels requires an understanding of the beliefs, representations, and coping strategies developed by populations directly concerned with fire risk and fire prevention in tunnels (Kouabenan, 1998, 2001, 2002; Kouabenan and Cadet, 2005; Kouabenan et al., 2007).

In this study, tunnel users are seen not only as agents responsible for their own and others' safety, but also as individuals whose actions are based on personal representations and beliefs (Kouabenan, 1999, 2001; Kouabenan et al., 2001). By viewing a road tunnel in the event of fire as a dynamic open system (Rogalski, 2003; Samurçay and Delsart, 1994), we postulated that any tunnel user who learns of a fire and is aware of the available safety or escape measures becomes, from that moment on, an actor who plays an integral part in the rescue operation. In reality, as mentioned above, when a fire occurs in a tunnel, not all users can be directly contacted and warned by safety personnel. However, those who are able to communicate with personnel can offer vital aid to others in the tunnel. The delegation of responsibility to tunnel users can only function effectively if they have a close-to-accurate representation of the risks involved, as well as a good knowledge of available courses of action. Clearly, the decision to evacuate can only be made after the assessment of available information about the immediate and imminent risks (Samurçay and Rogalski, 1993) and about who might be affected by those risks (oneself, others, a larger group, etc.). It is only through a better knowledge of tunnel users' fire-risk representations and awareness of safety devices that we can provide drivers with relevant information in real time, and that prevention measures likely to last – because they are geared to changing users' behaviors and attitudes – can be implemented.

The present study focuses on understanding two different phenomena: how users construct risk perceptions in tunnel-fire situations and how evacuation-behavior management evolves at both the individual and collective levels. In particular, our goals are to grasp how tunnel users with different experiences and practices in tunnels perceive fire-related risks, and to assess their awareness of intervention and rescue means, their degree of trust in the efficacy of these means, their cognitive strategies for coping with a fire, and any suggestions they might have regarding measures to combat fire dangers (safe areas, emergency exits, smoke-venting systems, alarms, etc.). We also look at users' perceptions of risks for themselves vs. risks for others (measure of comparative optimism), their perceptions of risk control and risk seriousness,

and their behavioral intentions if personally confronted with a tunnel fire. The psychology research on this topic has shown that such perceptions are in fact biased: individuals have a tendency to perceive less risk for themselves than for others (Weinstein, 1980). It has also been shown that an exaggerated feeling of control increases the optimism bias (Kouabenan, 1999; Causse, 2003; Causse et al., 2006). Such optimism can lead to a blind trust in one's abilities and in the available means for coping with risks, even risks that are uncontrollable from an objective standpoint.

In concrete terms, the aims of this study can be summarized as follows: (1) identify the representations of users regarding tunnel fires, and their assessments of fire risks for themselves and others; (2) evaluate tunnel users' awareness of rescue devices and means of intervention in case of a tunnel fire; and (3) determine the impact of risk perception and knowledge of rescue devices on the behavioral intentions of tunnel users during a fire.

2. Method

2.1. Material

We developed a questionnaire based on a document search, various discussions with tunnel specialists, site visits to tunnels, and an analysis of video footage from actual fires. The questionnaire consisted of five different likert-type scales (ranging from 1 to 5) designed to measure risk perception and safety-device awareness: perceived risks for oneself, perceived seriousness of the consequences of an accident or fire in a tunnel, perceived feeling of control, perceived risks for others, and a scale to measure anxiety. For each of these scales, the perception measures were derived by presenting participants with several different situations or accidental events (e.g., "having your vehicle catch fire in a tunnel", "being hit by another vehicle that is changing lanes while you're driving in a tunnel", "being suddenly faced with a fire in a tunnel", etc.). The anxiety measure was based on the emotion items of Endler and Parker's (1994) Coping Inventory for Stressful Situations (CISS), which evaluates reactions to stressful situations.

The questionnaire also included a section measuring participants' knowledge of rescue devices. A list of nine safety devices or pieces of equipment potentially found in French road tunnels was presented to the participants; for each device they were asked to indicate if it did or did not exist. Seven of the nine devices are generally found in tunnels (emergency call boxes, fire extinguishers, fire hoses, sidewalk, camera, emergency exits, parking places for stalled or broken-down vehicles) and two of them do not exist at all (rest areas, emergency P.A. system).

Finally, the questionnaire included a section designed to assess participants' behavioral intentions in the event of a tunnel fire. First, participants were asked an open-ended question regarding what they would do if suddenly faced with a fire in a road tunnel and if another vehicle crashed head-on into their vehicle. Then they were given short narra-

tives (two or three lines) describing three situations likely to occur in a road tunnel. For each situation, they were asked to choose – from a list provided in advance – the statement that best corresponded to what they would do in that situation (e.g., stop and call for help via mobile phone, try to pass through the smoke-filled area, travel on foot to an emergency exit, etc.). The three scenarios and suggested reactions to them were derived from exploratory interviews and from surveillance videos studied by the authors.

2.2. Participants

One hundred and fifty-one drivers from four different groups of tunnel users (ages 16–83, mean age 31), were interviewed: 38 professional fire fighters, 30 truck drivers, 39 regular drivers, and 44 driving-school students. Both the truck-driver and fire fighter groups consisted entirely of men (mean age: 36.4 and 33.6, respectively). The group of regular drivers consisted of 22 men and 17 women (mean age 37.3), and the group of driving-school students, 21 men and 23 women (mean age 18.9).

These groups were chosen because they differed in their tunnel-driving experience and frequency of tunnel use, in their awareness of tunnel-safety devices, and in their risk-handling experience. It has been found that frequent experience or confrontation of risk without harm can reinforce one's perception of control (Kouabenan, 2002). From this, we can surmise that regular tunnel users, such as truck drivers, will have a higher level of perceived control and will thus be more optimistic. Likewise, fire fighters, who presumably have a better knowledge of rescue devices, should be likely to perceive themselves as having more control in a tunnel-fire situation and thus show greater optimism.

The participants were interviewed at different times and places, according to their availability and their occupation: within or upon exiting a driving school (driving-school students), in freeway rest areas (truck drivers, regular drivers), or in a fire station (fire fighters).

3. Results

The data were processed by SPSS 10.0 software. The reliability of the risk-perception scales was tested using Cronbach's alpha. The reliability index obtained for the different scales was good: $\alpha = .72$ for the scale measuring risk perception for the self, $\alpha = .73$ for the scale measuring risk perception for others, $\alpha = .79$ for the perceived-control scale, $\alpha = .75$ for the perceived-severity scale, and $\alpha = .83$ for the anxiety scale. To test the hypotheses, we used mean comparisons, Student's *t*-test and ANOVAs.

3.1. Perception of tunnel-fire risk: perceived probability, control, severity, dispositional anxiety, and comparative optimism

Among the groups in our sample, the fire fighters perceived the greatest *probability of an incident* occurring in

a tunnel ($M = 2.51$), followed by the regular drivers ($M = 2.48$), the student drivers ($M = 2.39$), and finally the truck drivers ($M = 2.11$). These results are consistent with those obtained by Bellerose and Pilisuk (1991) and by Kouabenan (2002), which showed how experience affects risk perception. Having more experience with risk seems to lead to a greater perceived probability of its occurrence (fire fighters), but this may also decrease it, as is apparently the case for truck drivers.

Overall, our tunnel users exhibited *comparative optimism*, perceiving less risk for themselves ($M = 2.39$) than for others ($M = 2.77$) ($t = -6.69$, $p < .0001$): this corresponds to Weinstein's (1980) observations for other types of events. A single-factor analysis of variance showed that, to a marginally significant degree, the fire fighters were the most optimistic. They were followed by the regular drivers, the truck drivers, and finally the student drivers (mean comparative optimism scores: fire fighters = .51, regular drivers = .48, truck drivers = .35, student drivers = .16, overall CO mean = .36; $F(3,146) = 2.347$, $p < .08$). These results partially confirmed our expectations.

Likewise, we observed an effect of perceived control on level of optimism (see McKenna, 1993). The more the users felt they could control events, the more optimism they exhibited ($F(1,133) = 5.72$, $p < .03$). They tended to overestimate their own *power of control* with regard to that of others, which directly influenced their level of comparative optimism. In line with our initial hypothesis stipulating that having experience with risk increases perceived control, the fire fighters had a significantly higher perceived control score; next came the truck drivers, then the regular drivers, and lastly the student drivers (means: fire fighters = 3.04, truck drivers = 2.79, regular drivers = 2.37, student drivers = 2.27; $F(3,147) = 8.226$, $p < .0001$).

In contrast, there was no effect of *event seriousness* on optimism level, contrary to what one might predict from Rutter et al. (1998) results indicating an increase in comparative optimism for events seen as involving greater risk of death or injury. One possible explanation could be the fact that, as a whole, the participants judged the events presented to them as very serious (overall mean on a scale of 1–5: 3.95, S.D = .76). A single-factor analysis of variance indicated that the fire fighters perceived events as significantly more serious than the regular drivers did; next came the student drivers and then the truck drivers (means: fire fighters = 4.42, regular drivers = 4.23, student drivers = 3.82, truck drivers = 3.17; $F(3,147) = 26.73$, $p < .0001$).

Finally, regarding the relationship between anxiety and perception of fire risk, the participants' dispositional anxiety did not have an effect on comparative optimism. However, a significant interaction was found between tunnel users' anxiety level and their perceived control over the situation ($F(1,133) = 5.13$, $p < .03$). Those individuals who felt little anxiety in their daily life were more optimistic when they had the impression of being able to handle the situation (see Fig. 1). These people perceived less risk for

themselves than for others. The student drivers' proved to be generally more anxious than the regular drivers, the truck drivers, and the fire fighters (means: student drivers = 2.98, regular drivers = 2.72, truck drivers = 2.32, fire fighters = 1.88; $F(3,146) = 18.17$, $p < .0001$). One can assume, then, that tunnel users who are generally less anxious and who have a greater feeling of control might tend to disregard evacuation instructions.

3.2. Rescue devices and users' awareness of them

Information about tunnel conditions and traffic is sent to *central control posts,* where it is monitored by one or more safety operators. Control posts are located near the tunnel for larger tunnels (e.g., Fréjus and Mont Blanc), and some posts manage several tunnels (e.g. on freeways or in urban areas). Tunnels more than three hundred meters in length are required to be equipped with *safety recesses.* In these recesses, tunnel users will find one or more *extinguishers* and an emergency alarm device (*telephone or emergency call box* in freeway tunnels). Such safety recesses are not meant to be a place where a tunnel user can find shelter from flames and smoke during a fire emergency. In some tunnels, the safety recesses are glassed in for soundproofing purposes, in order to make communication more audible even when traffic is still moving.

Evacuation in the event of a fire is done through *emergency exits.* Emergency exits generally either lead into a ventilation passage that brings fresh, healthy air into the tunnel or go directly outside the tunnel (above the mountain if it is not too high, or through the side wall if it is not too thick). Some tunnels are equipped with emergency exits leading to a hollowed-out area in the wall, into which fresh air is piped and maintained under pressure to prevent the penetration of smoke and fumes. Depending on the structure, emergency exits are located every 150 m, 200 m, or 250 m, and are situated either on the left side, the
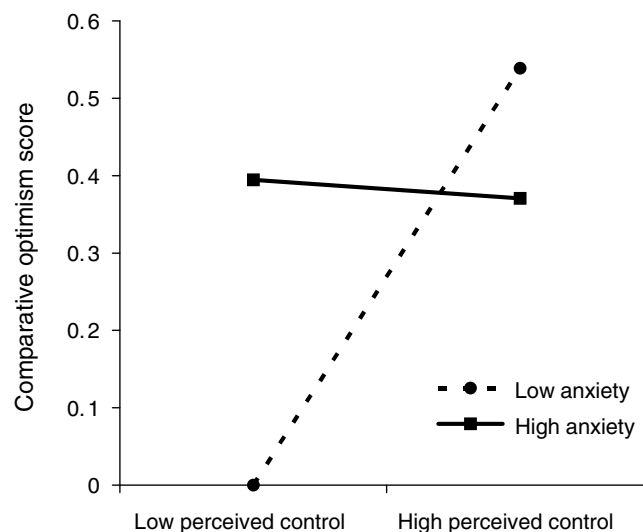

Fig. 1. Effect of perceived control and anxiety on comparative optimism.

Table 1
Percentage of fire fighters, truck drivers, regular drivers, and student drivers who said they thought various safety devices existed

Devices	Fire fighters (%)	Truck drivers (%)	Regular drivers (%)	Student drivers (%)	Entire sample (%)
Emergency call boxes	100.0	100.0	94.9	90.9	96.0
Fire extinguishers	94.7	100.0	74.4	70.5	83.4
Fire hoses	44.7	76.7	42.1	18.2	42.7
Rest area (does not exist)	21.1	3.3	30.8	9.1	16.0
Sidewalk	63.2	70.0	66.7	52.3	62.3
P.A. system (does not exist)	63.2	60.0	66.7	65.9	64.2
Camera	92.1	100.0	74.4	86.4	87.4
Emergency exit	84.2	100.0	82.1	100.0	91.4
Places for broken-down vehicles	36.8	50.0	30.8	25.0	34.4

right side, or alternating between the two sides, depending on the type of tunnel (two-way traffic, a single tube, or two separate tubes). All tunnels longer than three hundred meters contain *detection devices*. The various detection devices include smoke detectors (opacimeters), anemometers (for measuring wind speed in the tunnel), and carbon monoxide (CO) sensors. Some tunnels are also equipped with an *automatic incident detection system* that uses cameras to identify abnormalities such as immobilized vehicles or other objects blocking the road, any vehicles going the wrong way, or pedestrians in the road. When a user enters a safety recess, takes down an extinguisher, sends out a call by one of the available means (call box or emergency phone), or opens the door of an emergency exit, operators at the control post are immediately informed of this and can locate this person on a synoptic chart. In case of a problem, the safety operator informs the users about what's happening and what to do via an *FM radio* transmitter. Finally, the most recently-built and best-equipped tunnels have a programmable message board that provides information to drivers in real time.

Regarding overall awareness of devices, the truck drivers ranked ahead of the fire fighters; then came the regular drivers and finally the student drivers (see Table 1). Emergency call boxes, emergency exits, surveillance cameras, and fire extinguishers were the devices best known by users (96.0%, 91.4%, 87.4%, and 83.4%, respectively). Note that many people believed (wrongly) that there is a P.A. system to broadcast emergency messages (two-thirds of users). The existence of areas to park broken-down vehicles was only known by about a third of the users, perhaps because they only exist in long tunnels.

We observed a weak but significant link between awareness of safety devices and tunnel use ($r(141) = .17$, $p < .04$). The data indicated that the more users frequented tunnels, the more knowledge they had of safety devices. Likewise, the awareness level regarding safety devices was significantly and positively correlated with the mean number of kilometers travelled each week on national highways ($r(139) = .405$, $p < .0001$) and freeways ($r(138) = .355$, $p < .0001$), and with the number of years of driving experience ($r(139) = .210$, $p < .01$). However, knowing about safety devices did not necessarily lead to their spontaneous use. In fact, individuals who had a good knowledge of safety and rescue devices had a tendency to be less optimistic as event seriousness increased. Conversely, people with lower safety-device awareness were more optimistic as seriousness rose ($F(1,133) = 5.12$, $p < .03$). These findings suggest that the former users are well aware of the relative inefficiency of these measures or that the latter might be unaware of possible consequences (see Fig. 2).

During the interviews, the tunnel users said they were aware of the existence of standard, fixed-message road signs at tunnel entrances and exits, but that they did not really read them. This fact led us to doubt the usefulness of signals and notification systems in tunnels. Our own observations during visits to several tunnels, in the company of CETU specialists (Lyon Center for Tunnel Studies), showed that for cars travelling at a normal speed, these signals may not be noticed unless the driver knows of their location ahead of time (ergonomic problems with design, layout, visibility, etc.?). Signs with moving messages would perhaps be more widely read, but this hypothesis needs to be confirmed. Another avenue to explore would be the idea suggested by one user, namely, that emergency instructions could be provided on a case-by-case basis, for example, on the toll tickets of large tunnels.
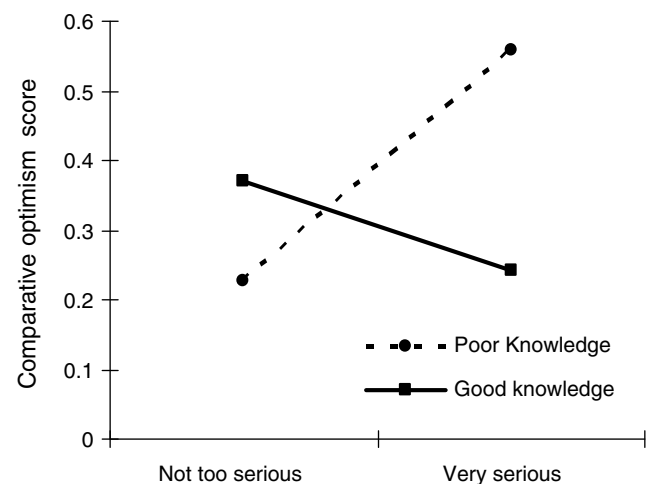
Fig. 2. Effect of safety device knowledge and perceived seriousness of consequences on comparative optimism.

3.3. Behavioral intentions in the event of a tunnel fire: evacuate the tunnel? inform rescuers? inform others? wait?...

In this section, we evaluate users' behavioral intentions in several typical situations. Two evaluation methods were used. First, participants were asked to spontaneously express their intentions in response to open-ended questions about what they would do in case of (a) a tunnel fire, or (b) a collision in a tunnel. Second, they were asked to read three scenarios of likely road tunnel incidents and then choose the behavior they would adopt from a list of proposed behaviors.

3.3.1. Spontaneous behavioral intentions in case of a fire or collision in a tunnel

3.3.1.1. Behavioral intentions during a road-tunnel fire. To the open-ended question: "You are surprised by a fire in a road tunnel. What do you do?", three main types of reactions were noted: evacuate (40.4%), exchange information (34.8%), and help others (13.2%).[1] In the case of evacuation, a majority of the tunnel users chose to look for an emergency exit (50.5%), as opposed to 32.7% who would move towards the tunnel exit and 16.8% toward the tunnel entrance. Thus, half of the users would choose the safest option. Among the factors that entered into the decision to use an emergency exit were the existence of a traffic jam or a severe fire. The method most often chosen for returning to the tunnel entrance was to make a U-turn (16%).

As for information exchanges, the majority of users (55.2%) would first of all alert rescuers, mainly by using a mobile phone (52.1% of the alerts vs. 18.7% who would use emergency call boxes). The former method (mobile phone) represents the least effective option. Note that only two individuals mentioned the potential difficulty of getting through to the mobile-phone network while in a tunnel. In second place, participants said they would exchange information with other tunnel users (36.8%), mainly by using their hazard lights (71.7%) or by making hand signals (9.4%). Few people (8%) said they would wait for official information, and only one person cited the radio as a means of getting information.

Finally, with regard to helping others – relatively infrequent compared to the other behaviors – the choice was often to use a fire extinguisher to fight the fire (39.4%).

3.3.1.2. Behavioral intentions following a collision in a tunnel. The situation and question presented to the participants were as follows: "A vehicle coming from the opposite direction hits the vehicle you are driving in a road tunnel. You only have a few scratches and your car can still be driven. What do you do?"

As above, the reactions expressed fell into three categories: information exchanges (48.7%), evacuating the tunnel (32.5%), or staying put (4.1%).[2] The main reason given for staying put was to write out an accident report (75%). Exchanges of information were done mainly to alert rescuers (30.3%) with a mobile phone (13.8% of the alerts), an emergency call box (6.9%), or a call to the control post (3.4%). The next type of information exchange was to warn other drivers (19.9% of the exchanges) by flagging the accident scene (57.6%), using one's hazard lights (31.6%), or making hand signals (5.3%). Among the users questioned, 31.4% said they would see if the other driver was all right, 14.6% would write up a report, and 4.2% would call road service. The evacuation behaviors consisted of moving toward the tunnel exit (16.7% of users) or in some unspecified direction (80.6%). Very few users would go toward the tunnel entrance (0.5%). The deciding factor for people wanting to get out of the tunnel seemed especially to be the fact that no one was injured (12.5%).

In conclusion, the behaviors spontaneously expressed by participants differed according to the situation under consideration. In the event of a fire, users said their priority would be to evacuate the tunnel, and a good portion would do so by the recommended method, i.e., via an emergency exit. In the event of an accident without a fire, informing rescue personnel and other tunnel users was the predominant choice, with evacuation being the second concern. However, in both cases it was regrettable to note that information was communicated mainly via mobile phone, which is a less effective method than using emergency call boxes (problems accessing the network, difficulty pinpointing the location of the caller, etc.).

3.3.2. Behavioral intentions reported following the presentation of tunnel incident or fire scenarios

3.3.2.1. Behavioral intentions when the driver of the vehicle in front communicates the necessity of evacuating the tunnel. In the first scenario presented to the participants, an incident happens 4 km into a 6-km tunnel. There is a traffic jam and the driver of the vehicle just ahead of the participant walks back to say that a fire has just broken out a little ways on, and that everyone must evacuate the tunnel. The participant is also told that no flames or smoke are visible. This scenario is similar to one we observed on a surveillance video: many of the drivers did not listen to the person who got information via radio, reacting to the situation in various ways. The following possible actions were proposed to our participants. They could choose a safety-conscious behavior: move towards an emergency exit (behavior recommended by international authorities); or some other, more dangerous behavior: stay in one's vehicle and wait for official information; stay in one's vehicle and turn on the air recirculation system (hypothesis advanced

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[1] For this question, 11.6% of respondents did not answer or gave vague answers.

[2] In this case, 14.7% of respondents gave a vague answer or no answer at all.

to explain the bodies found in vehicles during the Mont Blanc fire); leave the vehicle and go towards the presumed location of the fire (distance from the fire unknown); leave the vehicle and go towards the tunnel entrance (risk of being overcome by toxic fumes before reaching the entrance); make a U-turn with the car to get back to the tunnel entrance (risk of blocking the passage of rescue vehicles); or try to go forward with one's vehicle and pass through the smoke-filled area (risk of hitting another vehicle).

Our analysis of the participants' behavioral intentions showed that most of the users chose to look for an emergency exit (39.1%) or wait for official information (21.2%). Note that almost half of the truck drivers chose the safety-conscious behavior of heading towards an emergency exit (46.7%) as opposed to 39.5% of the fire fighters and 38.6% of the student drivers. However, a significant number of the fire fighters said they would wait for official information (31.6%). This can be interpreted either as a desire to be better informed so as to be able to assist authorities, or as a lack of confidence in the information provided by the general public. We could also relate this behavior to a greater perceived sense of control by persons in this occupational category, who exhibited the least amount of anxiety among the different groups interviewed here. The desire for official information among individuals most frequently faced with risks was also found by Perry et al. (1982) in the case of a volcanic eruption. Likewise, Proulx (1993, 2003) observed that when a fire breaks out in a high-rise building, it is common to find occupants hesitating for some time before evacuating. The data gathered during tunnel fire incidents confirms these facts (Dosne, 2002; Brocquet, 2002). One explanation may lie in the fact that people who have to manage a crisis tend to look for information about the situation and to evaluate possible actions before beginning to act (Papaioannou and Georgiou, 2003, cited by Papaioannou and Georgiou, 2003; Samurçay and Rogalski, 1993). This information-processing step takes time and is influenced by people's perceptions of the risks incurred (Rogalski, 1994). In itself, it is not an irrational approach, but it makes it difficult to predict individual behavior in the face of a fire.

In contrast, for the regular drivers, one of the most common secondary reactions to receiving evacuation information about a tunnel fire would be to make a U-turn (25.6%), which could be even more risky. This behavior may be due to drivers' personal attachment to their vehicles, sometimes to the detriment of safety-conscious behavior (in the Mont Blanc tunnel fire, more than 70% of the victims died in their vehicles). We also found behaviors like those observed in the actual situations analyzed in our study on risk management (Kouabenan et al., 2005).

Comparative optimism was not found to have a significant effect on behavioral intentions ($\chi^2 = 6.140$, $df = 6$, $p < .53$). By contrast, there was a marginally significant effect of level of awareness on behavioral intentions ($\chi^2 = 10.678$, $df = 6$, $p < .10$). Among the individuals with

a good knowledge of rescue devices, 46.5% said they would move towards an emergency exit (a safety-conscious behavior) versus only 32.9% of the individuals whose knowledge of these devices was poor.

3.3.2.2. Behavioral intentions when a car parked on the side of the road with people inside starts to emit smoke. The second scenario presented to participants recreated a striking scene we had observed in a surveillance video. The incident occurs in the middle of a road tunnel that is 6 km long. A car stopped on the edge of the pavement has clouds of smoke billowing from it; the tunnel is filled with smoke but a faint light is visible on the horizon. The participant is told that it is possible to see the vehicle's occupants who are waiting on the road. Among the possible behaviors, the participant could choose a joint, safety-conscious action: go with the vehicle's occupants on foot to look for an emergency exit (the recommended action); an individual, safety-conscious action: go alone on foot to find an emergency exit; an individual but unsafe action: try to pass through the smoke-filled area (risk of getting in an accident); or one of several joint but unsafe actions: stop to see if the vehicle occupants need help and stay with them (risk of being overcome by toxic fumes); stop and call for help by mobile phone (problems accessing the phone network and failure to indicate the fire's location); pick up the vehicle's occupants and then drive through the smoke (risk of an accident); or pick up the vehicle's occupants and make a U-turn to go back out of the tunnel (risk of an accident and of blocking the way of emergency vehicles).

Overall, the behaviors cited most by users were: going out an emergency exit with the occupants of the burning vehicle (26.2%); trying, with the occupants on board, to drive forward (19.5%); and stopping to make a call with a mobile phone (18.1%). The fire fighters' responses were divided almost entirely between going with the vehicle's occupants towards an emergency exit (37.8%) and trying to drive with the occupants through the smoky area (35.1%). Among the truck drivers, the behavior chosen most often was trying to drive alone through the smoke (26.7%), followed by looking for an emergency exit with the occupants (20%), and then stopping and calling with a mobile phone (20%). As for the regular drivers, their responses were divided nearly equally between going with the vehicle occupants toward an emergency exit (26.2%), stopping and making a call with their mobile phone (23.7%), and making a U-turn after picking up the occupants of the burning car (23.7%). The student drivers adopted almost all the behaviors equally often, with a slight preference for stopping and calling on a mobile phone (22.7%) and heading for an emergency exit with the occupants of the burning vehicle (20.5%). It is worth noting that, as a whole, few users would choose the recommended behavior in this situation (at the most one-quarter in each group except the fire fighters, the most knowledgeable). Note also that more than a quarter of the truck

drivers would go alone through the smoke; this is dangerous and testifies to a certain uncaring attitude on the part of these drivers who spend a great deal of time on the road. Likewise, other than the fire fighters, most of the drivers said they would use their mobile phone to call for help, a relatively ineffective solution.

Finally, the participants' behavioral intentions in this situation on were not significantly affected by comparative optimism ($\chi^2 = 7.751$, $df = 6$, $p < .26$) or level of awareness ($\chi^2 = 5.034$, $df = 6$, $p < .55$).

3.3.2.3. Behavioral intentions when the user's own vehicle starts to emit smoke in a tunnel. The third narrative described an incident in which smoke starts coming out of the hood of the participant's own car in the middle of a 6-km long tunnel. Participants had to choose between a safety-conscious behavior: continue to drive in the direction of the exit (the fact of driving helps smother the fire[3]); and several other behaviors that are more dangerous or not recommended: pull over and look for an extinguisher (the fire could flare up and the smoke could cause panic or an accident); pull over and look for an emergency call box (same risk as above); pull over and call the fire department using a mobile phone (problems accessing the network and pinpointing the location of the call); park the car on the side of the road and try to hitch a ride in another vehicle (risk of getting hit by another vehicle coming at a high speed); or continue driving in the direction of the exit while calling the fire department on a mobile phone (risk of an accident and problems getting through with a mobile phone).

The results showed that the behavior chosen by most of the users in this situation was to stop and look for an extinguisher (26.5%), an action that is not recommended. The next most commonly chosen behavior was to head for the exit with one's vehicle (25.1%) – a safer course of action chosen by a majority of the truck drivers (53.3%) and a good portion of the fire fighters (31.6%), the two best-informed groups among the participants. Note, however, that the fire fighters still mainly chose to continue driving toward the exit while calling rescuers on their mobile phone (36.8%). In contrast, among the regular drivers, the largest portion indicated they would stop and use an emergency call box (28.2%), whereas the student drivers would first choose to stop and use an extinguisher (40.9%), then stop and call from an emergency box (31.8%). Thus, in these groups, risky behaviors were more common than safety-conscious ones. In summary, only one-quarter of the people questioned would adopt the recommended behavior in this situation. Among these individuals, a large number

had a great deal of experience with tunnels and/or risks (truck drivers, fire fighters).

There was no effect of comparative optimism on behavioral intentions ($\chi^2 = 8.40$, $df = 5$, $p < .14$). In contrast, we did observe a significant effect of awareness of emergency devices on behavioral intentions ($\chi^2 = 12.491$, $df = 5$, $p < .03$); the knowledgeable people were more likely to adopt a safety-conscious behavior (to continue on their way towards the exit) than those with little knowledge (35.2% and 15.2%, respectively).

4. Discussion and conclusion

Our study demonstrated that tunnel users have a strong level of awareness regarding safety devices. However, we also noted that knowledge of safety devices did not necessarily lead to their spontaneous and efficient use. When we asked users how they would behave if their vehicle caught on fire, many people selected ''use a fire extinguisher'' from a list of behaviors, but few mentioned this action when asked an open-ended question about what they would do, in spite of the fact that a majority of them said they knew there were fire extinguishers in tunnels. Likewise, while many users knew about emergency exits in tunnels, many of these same people said that in the event of a fire, they would try to get out via the tunnel entrance or exit, even if they were in the middle of the tunnel where there is little chance of escape. In the same vein, most of the participants said they would use their mobile phone to notify road-safety personnel, even though, unlike emergency call boxes, this does not allow personnel to quickly locate the fire[4]. In sum, while most of the individuals interviewed were well aware of the various safety devices, they apparently do not use them automatically. For long-term prevention, safety campaigns should therefore not only inform users about existing safety devices, but also explain why it is vital to use these devices as opposed to taking other possible actions. Effective prevention cannot be achieved solely through awareness of safety devices, but also requires knowledge of how to use such devices and an understanding of the importance of doing so.

Furthermore, different field observations made in various tunnels during our work (the present article makes only a partial report), showed that the ergonomic design of the devices as well as the way the different information are communicated to the users were also in question. It seems then important to initiate a work on the ergonomic designing of the tunnel safety devices and signals, but also a work on the content and the amount of information provided at once to the tunnel users.

Concerning safety equipments, it seems necessary to standardize the devices in tunnel (size of safety recesses, resistance to heat, etc.).

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[3] An incident that occurred in France in 2004 demonstrated the utility of continuing to drive after a fire starts in one's vehicle, for as long as the engine is operational. On January 19, 2004 in Dullin, France, a motor coach caught on fire (the fire was in the engine at the rear of the vehicle); the bus driver continued driving, exited the tunnel, and safely evacuated the passengers once outside. This behavior most certainly prevented another catastrophe of the Mont Blanc type.

[4] Only those who use emergency call boxes can come into direct contact with safety operators.

Concerning the signals, it may be useful to adapt the form, the localization and number of signals to the information processing capacity of the tunnels users' (limit the number of road-signs at the entry of the tunnel, provide signs of large size and reflecting, etc.).

Concerning the messages to the users, harmonize and limit the number of information in each message (a lot of details could be a constraint for a good memorization), target or distinguish two categories of messages: a first category providing messages on how to behave to avoid any accident in tunnels (observance of speed limit, switching on headlights, observance of security distances, etc.); a second category of messages bearing on the behaviors to observe in case of an accident or a fire in road runnels (how to inform rescue staff, how to give the alarm, how to evacuate, etc.). Further studies must be conducted in order to test these different provisions and messages with the objective to make them easier to perceive and to harmonize them at the international level.

Effective and long-lasting communications about safety should consider the characteristics of the audience to whom they are addressed. Messages should be specific and adapted to the beliefs of the target audience. In general, users' awareness of effective evacuation and warning behaviors varies according to the user category, but is limited in all cases, and it is far from reflecting the expected behaviors. Even fire fighters – who are regularly involved in fire-related interventions – and truck drivers – who pass through tunnels daily – do not appear to be totally familiar with safety provisions in tunnels. For example, while the truck drivers and fire fighters knew that if their vehicle should catch fire in a tunnel it is important to continue moving forward for as long as possible, this behavior was encountered less frequently among the regular drivers and the student drivers. Thus, information about this problem should be included in both driving-school courses and prevention campaigns targeting regular drivers. As a whole, the student drivers interviewed for this study seemed to be more poorly equipped for handling a tunnel fire than the other drivers, although our conversations with them indicated their curiosity and need for tunnel-safety information. We recommend that a "fire safety" module be included in driver's training courses. Some European countries (e.g., Switzerland) already include training on emergency rescue and fire in their student driving courses. What's more, it became evident here that having more experience with tunnels and with driving in general improves people's awareness of fire-safety procedures, but does not necessarily mean greater compliance. In fact, other studies have shown that higher levels of experience can lead people to dangerously underestimate risks and to neglect safety measures (Kouabenan, 2002; Kouabenan et al., 2007). Further sensitization and renewed vigilance among experienced drivers and people who frequently use tunnels would therefore be useful. It is crucial that these groups do not interpret their good fortune in these situations as an absence of risk, and that they perceive the importance of always being prepared to cope with danger.

Planning for risk prevention in fire incidents should rely not only on safety measures concerning tunnel evacuation, but also on methods for disseminating informational and alarm messages. Indeed, managing alarm information is just as important as managing evacuation information. How can awareness of a fire – or more specifically the perception of danger signs – be enhanced? In this study, for example, we found that many drivers would waste time calling on their mobile phone to warn authorities instead of immediately using the emergency call boxes designed specifically for this purpose. Similarly, we found that participants tended to perceive themselves as less vulnerable than others, and that this idea was linked to their greater perceived control. This may lead them to engage in risky behaviors or to neglect safety recommendations (Kouabenan, 1999; Kouabenan and Cadet, 2005). The results of this study suggest that long-term prevention should focus more on tunnel users' perceptions and knowledge in order to help users avoid unwise actions, in particular by placing priority on effective ways of modifying drivers' perceptions of risks and on improving the way alarm and evacuation messages are presented.

This implies a radical change of attitude among responsible parties as to where and how to allocate fire-prevention and safety resources. One way for transportation authorities and tunnel builders to resolve the permanent conflict between safety concerns and profit goals would be to integrate tunnel users' needs and attitudes into projects for upgrading physical tunnel systems and organizing the associated safety procedures. Programs to evaluate and manage fire risks in tunnels will ultimately be more effective and long-lasting if the representations and beliefs of tunnel users are given full consideration at the planning stage. In this study, for instance, we found that users with better knowledge of existing safety and rescue devices are less confident and optimistic when the risks are deemed serious. Yet people's confidence in the effectiveness of existing prevention measures is one of the conditions for their use and their success (Weinstein, 1993). Of course, such carefully tailored and targeted prevention messages are more costly to design and implement, but the results would be more durable and more effective, because they are geared to actual tunnel users, i.e., those who must implement the safety procedures. In any event, prevention campaigns should focus more on specific actions such as how to send out an alarm, and on the best evacuation procedures and steps to take in case of a fire, etc. This is important, as mentioned above, because it became apparent here that many drivers faced with a tunnel fire would waste time waiting for official instructions or making a call with their mobile phone, putting themselves at risk for being overcome by toxic gases.

Acknowledgements

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