HUMAN BEHAVIOUR IN TUNNEL ACCIDENTS

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INTRODUCTION

Accidents occur less frequently in tunnels than on open roads, but their consequences often are more serious. After the severe tunnel accidents in the Montblanc (1999) and Gotthard tunnel (2001) various studies on tunnel safety were conducted. These studies mainly focused on possibilities to improve safety with new technical developments, but mostly neglected human factors - although human misconduct in 95% of all cases is responsible for traffic accidents[1] and maladaptive behaviour may lead to their own death. For example, in the Montblanc tunnel fire, people who were caught up in the traffic jam and could not see the accident, did not or too late initiate self-evacuation. This disengagement also occurred in simulated tunnel emergency experiments with smoke. For example, in spite of dense smoke in front of them some participants remained in the car and some refused to leave it despite instruction[2]. Until now, our knowledge about human behaviour in such emergency situations is spare. Connection to psychological theories may provide new insights.

The way from perception to action in emergency situations involves complex processes which may be simplified by different steps: First, the stimulus indicating a risk or stressful encounter has to be assessed, encoded and identified. Second, the stimulus and coping expectancies have to be evaluated. Cognitive processes are of minor importance for unequivocal dangerous stimuli which likely elicit impulsive behaviour such as freezing or avoiding. Other less intriguing stimuli pass through elaborative cognitive processes, establishing a reflective way of action regulation[3]. Last, coping behaviour and some principles of action regulation may be applied to disengagement at risks.

This article aims to elucidate possible moderators and modulations of human behaviour in tunnel accidents. Considering the complexity from perception to action and considering the multitude of theories and studies only a short survey of risk perception, cognitive appraisal processes, coping styles and action regulation will be given.

PERCEPTION

Perception is a highly complex process. It consists of transformation of stimulus information via sensory channels, encoding and stimulus identification processes by combining features and comparing them with long-term representations. Often several sensory channels altogether will be taken into account. Olfactory or thermoreceptoric sensations hardly affect people in tunnels and even acoustic sensations play a minor role, because most drivers have their windows closed in tunnels. They mainly rely on visual impressions, their perception is narrowed.

Perception is based on a fast interplay between data-driven, bottom-up and top-down processes. Distinct signals (like fire) draw attention and force perceptual processing with a strong association to response patterns. Other stimuli, like smoke, grow continuously. The first signals are weak and difficult to detect; the discrimination between a relevant signal and noise is hampered. In these situations, top-down influences from personal motives, prior experiences and expectancies or emotional states bias/affect not only perceptual sensitivity (processes of information uptake) and decision criteria (amount of information that is required to accept a conclusion and to terminate information uptake)[4], but also responses[5]. Examples therefore are cognitive biases, related to anxiety[67], shifts induced by cognitive overload[8] and enhanced sensitivity of the perceptual system in detecting and processing danger signals if there is a belief of control or if consequences can be avoided[9].

As shown by analyses of tunnel emergencies (for example Montblanc, Tauern), people involved in or nearby the accident are more likely to survive than people far away from the hazard. Although the physical threat is higher for the first group, the faster and unambiguous perception and interpretation of the danger facilitate and fasten adequate responses.

COGNITIVE APPRAISAL AND STRESS

Although not completely separately, interpretation processes may start after perception. In unequivocal dangerous situations further cognitive processes are of minor importance for the regulation of action. Avoidance behaviour is elicited immediately and automatically via associative links, the so called impulsive system controls behaviour[10]. For example, in fire most people react immediately by expanding distance to the hazard[11]. The second operating principle - termed reflective system - comprises behavioural decisions which are based on the knowledge of facts, probabilities and values. The behavioural outcome of reflective processes shows high level of variance between and within individuals, just as behaviour of tunnel drivers varies in smoke. Impulsive and reflective principles interact at different stages and allow flexible responses to environmental influences[12]. The reflective principle may incorporate cognitive processes as assumed by appraisal theories developed to explain human behaviour in stressful encounters such as tunnel accidents.

Three consecutive appraisal processes are assumed[13]. First the incoming signal is evaluated on its relevance for the individual`s well-being and on its valence (first appraisal). This depends crucially both on perception of and information about the impact or consequences of the stimulus. Thus, primary appraisal is influenced by prior experiences and familiarity to stressful encounters.

Secondary appraisal means the evaluation of resources, constraints, and options - if anything can be done to prevent or overcome harm. It relies both on individual resources and on risk judgment. Individual resources are for example prior experiences, belief of self-efficacy, locus of control or expectancies of success. Risk judgment contains five factors - controllability, visibility, tearfulness, possibility and severity[14]. Flames can be uniquely categorised, whereas smoke is a fuzzy entity that permits a number of specific estimates. Coping beliefs are low if individual resources are low and/or risk evaluation is high, leading rather to disengagement than to systematic problem solving. Secondary appraisal processes can be biased. First, anxious people overestimate the potential dangers and underestimate their own safety potentialities[15]. In general, high risk perception and low self-efficacy belief result in more anxiety, high motivation to seek information, but lower ability to retain information in contrast to a responsive attitude (high risk perception and high self-efficacy belief)[16]. Second, judgement failures occur: people base their estimations mainly on the possible, catastrophic outcomes and neglect the low base rate of severe harms leading to low expectancies of successful coping[17]. Thus, both ways amplify the fear-regulating feedback-loop.

Primary and secondary appraisal processes converge to determine the overall judgment of the current situation (re-appraisal), accompanying emotions, physiological processes and behavioural outcomes. Stress emerges when goal-directed activity is disrupted and the demands and pressures of a current situation exceed the estimated resources. Stress is reflected in subjective ratings and physiological change (e.g. increased heart rate and skin conductance level)[18]. For example, in virtual tunnel drives psychophysiological responses to phobic fear were assessed[19] and a darkness-enhanced startle response was observed[20].

COPING STRATEGIES

Coping denotes the efforts made to deal with the demands of stressful situations. If the expectancy of successful coping is sufficiently positive, efforts are invested - if it is sufficiently negative, people disengage from further efforts. The value and viability of coping responses depend crucially on situational variables and on action options, whereas the plurality and availability depend on individual resources or motives (regret, ambiguity or loss aversion[21]). Thus, aggravation of an individual “overall” coping score or differentiating between maladaptive or adaptive composites are not useful. More appropriate is a rough classification system according to two questions: Does coping result in passive or active exposure to the problem or, alternatively, is the coping skill problem- or emotion-focused? Examples for active or problem-focused skills are for example systematic problem-solving, seeking for social support, reframing, altering the situation, escape behaviour. Denial, daydreaming, drinking, distancing, drawing off attention and avoidance are rather passive or emotion-focused. Active strategies seem to be advantageous to cope with daily stress on a working day (like seeking for social support or facing the problem and seeking for solutions), they result in less stress experience and less cortisol output (a powerful indicator of stress level) than passive coping styles (e.g. avoidance[22]).

Several influencing factors on coping were found empirically: High stress levels[23]or pessimistic expectancies[24] enhance the likelihood of passive coping strategies (like trying to avoid thinking about the problem and rejecting goal-relevant information). Similarly, stress believed to be unchangeable enhances distancing and escape-avoidance responses[25], and threat of physical health is associated mostly with increased seeking for social support and escape-avoidance behaviour. Seeking for social support or building relational groupings and a network system with individuals aim to facilitate the decision process by an additional information uptake or help. Otherwise, if intergroup information provides a basis for social judgment, assimilation effects can lead to disengagement. All feel a rope of sand and do not seek shelter[26].

The problem of avoidance-avoidance conflict may delay selection of coping behaviour[27]. Two behavioural tendencies are activated simultaneously with equivalent strengths and they are incompatible with each other. People are confronted with the necessity to choose between two undesirable alternatives. This decision and the emotional state of vacillation amplify stress responses and further impede and delay decision making. For example, on one hand people want to leave the car and go afoot to the emergency exit, on the other hand they want to stay in their car, because they fear loss of orientation or they are afraid of theft of their properties from their vehicle. The situation is a stable equilibrium and the conflict can be solved only by changing the situation such that one alternative can be preferred, i.e. the smoke grows thicker and physical threat becomes more obvious, thus lowering the worries about of personal belongings.

A second point why people delay their response behaviour and inhibit action impulses although they are ready for performance may be that they wait for instruction by authorities. For instance, this has been shown for hierarchically structured environments, such as trains, hospitals or nursing homes[28].

DISENGAGEMENT

Various focal points have emerged which influence both decision process and reaction time. Naturally this list is not exhaustive, but it allows insights into human behaviour at risk in tunnels and offers ideas for research questions. So far none of the theories have been systematically applied to tunnel accidents.

1. Conservative thresholds in perception, judgment and response result in delayed or absent risk awareness.
2. In the first appraisal process the stimulus is evaluated as “irrelevant” (due to hampered perception or information deficit about the real physical threat).
3. Secondary appraisal results in low coping beliefs and an acting block.
4. Secondary appraisal results in further information uptake: People wait before they decide to act. This can be a functional precursor of systematic problem-solving and is per se active and adaptive (although overt behaviour seems to be inactive). The crucial point may be that in tunnels the time period of successful self-evacuation is limited and active behaviour should start immediately to avoid severe harms. Delayed responses strengthen deteriorating expectancies and impede further initiation of self-evacuation, especially in the context of social assimilation.
5. People want cannot decide between contrary action tendencies.
6. People are misguided and expect an order or instruction of a public risk management (e.g. tunnel-operator) and remain inactive until they receive a prompting signal.

REDUCING DISENGAGEMENT

Overriding disengagement aims to both enhance active behaviour and fasten self-evacuation. Safety training was established as a useful tool to improve risk perception and establish control beliefs[29].Moreover, information and instruction were found to reduce disengagement and accelerate reaction times[30].

Information about adequate behaviour in tunnels and safety installations establish functional action options, increase the trust in public capabilities and may abbreviate the decision process. An increased trust could be a potent factor, because advances in technology as well as dreaded and uncontrollable risks are perceived as deserving public and not private risk management[31]. Furthermore, intention implementation (if-then plans) regulates emotional reactivity and reduces fear reactions[32] without taxing deliberative processes or cognitive resources[33]. This effect accrues from heightened accessibility of specified situational cues and strong opportunity-response links.[34] Information and education are shown to improve knowledge about risk factors, risk awareness, risk-taking choices in traffic[35] and evacuation behaviour[36], but they are not related to the accuracy of risk perception[37].

Instruction directly given in stressful situations seems to overcome disengagement because of three reasons. First, the influence of deteriorating expectancies on behaviour may be weakened or removed from the pressure of the current situational forces by establishing confidence. Second, self-focused attention may increase doubt on a successful outcome and shift expectancies further toward the negative. Instructions are attention-grapping and may interrupt self-monitoring loops, strengthen firmly established self-efficacy beliefs and regulate behaviour into active self-evacuation[38]. Third, under stressful encounters required resources may exceed available resources and a cognitive overload might occur which can be abandoned by clear instructions what to do[39].

FURTHER RESEARCH IDEAS

Following tunnel fires in the last decade many efforts were discussed and realized to improve tunnel equipment. For instance, new emergency lighting to facilitate risk perception, information brochures to influence self-efficacy beliefs, emergency signs to fasten self-evacuation[40], broadcasts in television or radio to inform about adequate behaviour in tunnels and to operate as intention implementation methods, and tunnel-operators to have available detailed emergency plans which involve communication with tunnel drivers and therefore to affect action regulation. Additionally, safety installations were improved to alleviate the consequences of disengagement. However, up to now, the effects of these safety improvements on human behaviour and reaction times have not been studied systematically. Moreover, the relevance and validity of the presented theories have to be evaluated, since based on these theories useful tools to overcome disengagement, for instance information and instruction may be developed.

In particular, experiments in virtual reality are suited to tackle these research questions. In virtual reality people experience the tunnel environment under controlled conditions. Advantages are the possibilit**ies** to combine subjective, physiological and behavioural data, to repeat the procedure easily, to manipulate specific factors and to control for ceteris paribus conditions simultaneously. The financial and organizational costs of virtual reality experiments are acceptable. Moreover, during the whole experimental procedure participants are accompanied by the experimenter and further tunnel drives after the emergency test drives can minimize peritraumatic stress and avoidance behaviour. Virtual reality readily has been proved in several studies as a useful[41] and valid method: it produces adaptive responses[42], is suitable for emergency simulations[43] and for use as an effective training tool[44].

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