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Mental models in warnings message design: A review and two case studies

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ABSTRACT

This article examines how people access, evaluate and process information and reviews the psychology of risk perception literature in order to draw out key considerations for effective message design. Two case studies of chemical consumer products illustrate the implementation of the mental models methodology in designing risk communications, combining a quantitative technical assessment of a hazard with qualitative methodologies for assessing beliefs and behaviors that are key determinants of risk. The case studies emphasize the importance of considering not only intrinsic properties of a hazard but also the specific cultural and behavioral decision-making context.

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1. Risk communication and human factors in message design

The research in both the risk analysis and the human factors literatures points to the centrality of understanding users' risk perception or hazard perception in designing an effective warning or risk communication. Whether the theoretical approach is grounded in value-expectancy theory (Fishbein and Azjen, 1975), social learning theory (Bandura, 1977), protection motivation theory (Rogers, 1983; Witte, 1992), the mental models methodology (Morgan et al., 2001), or the Communication-Human Information Processing (C-HIP) model (Wogalter and Laughery, 1996), research findings point to a critical role that a person's beliefs about a hazard plays in their information processing and decision making about that risk. Among these approaches, the mental models methodology has served as an important link between the two fields of risk communication and warnings design, appearing in applications as disparate as computer security (Alsabbagh and Kowalski, 2011; Camp, 2009; Bravo-Lillo et al., 2011), flood forecasting and risk management (Dufty et al., 2012; Dolif et al., 2013; Lazo et al., 2010), cigarette smoking (Gygax et al., 2010), and adaptive cruise control (Beggiato and Krems, 2013).

While several of the existing models of risk perception include a consideration of social influence on individual decision-making processes, researchers continue to seek out ways to incorporate cultural considerations into risk perception models. For example, Kahan et al. (2006) proposed a theory of cultural cognition of risk that combines an earlier-developed cultural theory (Douglas and Wildavsky, 1982) and psychometric approaches (Slovic et al., 1979) to risk. Smith-Jackson et al. (2010), for example, have considered cultural factors in risk communication about pesticides among farm workers.

How ought risk communicators take risk perception into account in the creation of warnings? What perceptions do people bring to an interaction with a warning, and how do the warnings, in turn, influence people's perceptions of risk? The literature on risk perception and risk communication provides a rich set of findings in answer to these questions. Here findings are considered in light of present trends that pose challenges and opportunities for risk communication: increased quantity of information, increased sources of information, and globalization's call for consistency as well as specificity across and within nations and cultures.

The literature review that follows is divided at the first level into two categories: effects of existing risk perceptions on how warnings are read/perceived/designed, and effects of warnings on risk perceptions.

2. Risk perception influences how warnings are perceived (or designed)

When people approach a hazard, or a warning about a hazard, they come to the situation with existing beliefs and attitudes shaped by life experience, personal psychology, and previous encounters with similar hazards or similar warnings. Their beliefs may be partial, or complete and accurate or inaccurate in varying respects, informed by, among other things, culture and social location. Whether designing a warning, or seeking to understand a person's decision-making and action in response to risk, it is

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important to first gather information about the person's existing beliefs and attitudes. Together, a person's beliefs and attitudes will guide their approach to a warning or a hazard, influence their propensity to notice or read a warning, determine the information they will consider to be relevant or credible, the concepts they may struggle to accept, and the information they may perceive as old or redundant.

Risk perception affects users' behavior at all stages of interaction with a warning. Heightened hazard perception makes one more likely to notice (Godfrey et al., 1983), read (Donner and Brelsford, 1988; Frantz, 1994; Friedmann, 1988; LaRue and Cohen, 1987; Otsubo, 1988; Silver et al., 1991; Wogalter et al., 1991; Young et al., 1990), believe (Beltramini, 1988), and comply with (Frantz, 1994; Friedmann, 1988; Leonard et al., 1986; Otsubo, 1988) warnings (see also DeJoy, 1999 for a review of this literature).

Research has established that people's perception of risk is multi-dimensional, that is, it is shaped by multiple factors including the qualities of the risk itself (NRC, 1989). Classically, relevant dimensions of risk-affecting perceptions include voluntariness, familiarity, controllability, severity, certainty, and immediacy of effects (Slovic et al., 1979; Slovic, 1987). Vaubel and Young (1992), working with Slovic's framework, studied participants' perceptions of 40 products and determined that the level of hazard perception and precautionary intent were significantly influenced by factors including uncertainty about the hazard, (un)familiarity, immediacy of adverse effects, and magnitude of harm.

Wogalter et al. (1999) considered severity of consequences and likelihood (probability) as separable components of hazard perception. Whereas in Slovic et al. (1979), likelihood is the dominant factor in risk perception, severity was the primary determinant of hazard perception for consumer products. Wogalter et al. (1999) compared perceptions of likelihood and severity for a list of consumer products and the list of risks used by Slovic et al. (1979). The consumer products tended to be more familiar and have lower perceived risk (in terms of both severity and likelihood) than the list from Slovic et al. (1979). For the consumer products, injury severity was a stronger determinant of risk perception than likelihood. One explanation offered by Wogalter et al. (1999) is that the risks on the Slovic et al. (1979) list may pass some threshold of severity (e.g., death) such that likelihood becomes the dominant determining factor for risk.

Hellier et al. (2007) sought to consider the multidimensionality of signal words, though they did not utilize the Slovic schema. The extent of risk implied and the explicitness of instruction given were found to be salient dimensions of signal words. The results suggest the value of connecting warning signal words with specific situations in which they are most relevant. This necessarily entails attention to context and a customization of risk communication for intended audiences.

2.1. Familiarity and experience

The more familiar people are with a product, and the more experience they have using it, the lower the level of perceived hazard. Dejoy (1999) notes in his review that familiarity has been shown to decrease perceived hazard levels (Goldhaber and deTurck, 1988a; Karnes et al., 1986), decrease propensity to read warnings (LaRue and Cohen, 1987; Otsubo, 1988; Wogalter et al., 1991), decrease warning credibility (Andrews et al., 1991), decrease intent to take precautions (Wogalter et al., 1993), and decrease compliance (Goldhaber and DeTurck, 1988a, 1988ab; Otsubo, 1988; Wogalter et al., 1995).

Familiarity is bred not only through direct experience, but also through observation of use, exposure to advertising, or experience with similar products (Ortiz et al., 2000; Rhoades et al., 1990).

2.2. Availability

Users initially contact a warning with existing risk perceptions influenced by prior experiences and subject to cognitive heuristics. The availability bias (Tversky and Kahneman, 1974), for example, describes the way in which more salient (vivid, memorable) events are judged to be more frequent than less salient ones, producing an effect in which lay people overestimate the risks of rare events and underestimate the frequency of common ones (Lichtenstein et al., 1978). The warnings literature has documented similar biases in consumer estimates of product injury risks (Brems, 1986; Martin and Wogalter, 1989; Wogalter et al., 1993).

Media reporting can influence the availability bias by over-reporting rare events or by producing sensationalized content. Availability biases are shaped by the information individuals choose to process out of a flood of choices. While on the one hand, many hail the democratization of information on the Internet, allowing for more sources of information, the ways in which individuals self-select this information and the ways in which search engines privilege some results over others filters and mediates information in particular ways that stand to influence people's availability bias (Introna and Nissenbaum, 2000).

The current political debate over net neutrality (Wu, 2003) weighs commercial interests of telecommunications companies seeking advantages in access to bandwidth against the interests of individuals or small organizations seeking to communicate peer-to-peer. Ultimately, a bandwidth-based weighting of information sources will introduce a new set of biases.

2.3. Overconfidence

Another important systematic cognitive bias related to risk perception is overconfidence, or the idea that an adverse event will not affect an individual, despite correct likelihood estimates (Bohannon and Young, 1993; Creyer et al., 2002; Fischhoff et al., 1977; Slovic et al., 1980; Svenson et al., 1985; Weinstein, 1987). Weinstein (1980) has attributed this sense of personal immunity to an optimism heuristic in which individuals overestimate probabilities for positive life events and underestimate negative ones. Sjöberg and Drottz-Sjöberg (1994) label the difference between estimated risks to the general population and estimated risks to self "risk denial" and attribute it to the perceived controllability of a risk. In their study of 21 risks, the risks that are subject to individual control (e.g., smoking, drinking) had greater risk denial than those with low controllability (e.g., global climate change).

Culture can influence where and how availability and overconfidence biases are manifest. Lippa and Klein (2005) have argued for further consideration of national differences across human factors research areas. Smith-Jackson (2006) reviewed the literature on cultural factors in warnings design. She argues that culture can be thought of as a cognitive schema that shapes one's understanding of the world, including risk constructs. She reviews literature that has established particular cultural variations in risk perception that need to be taken into account in design of warnings, including risk aversion/seeking, self-efficacy or control over risk/fatalism, and individualism/collectivism. Smith-Jackson emphasizes the need to take into account differences in the levels of cultural distinctions people may draw in particular settings, and to consider acculturation or extent of cultural identification individuals may have with a larger group. In short, it is necessary to understand the audience both cognitively and culturally and to tailor warnings accordingly.

3. Warnings influence perception of risk

In the previous section, a number of key factors that influence a person's extant perceptions of risk as they approach a warning

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