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Risk Perception: Reflections on 40 Years of Research

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Numerous studies and practical experiences with risk have demonstrated the importance of risk perceptions for people's behavior. In this narrative review, we describe and reflect upon some of the lines of research that we feel have been important in helping us understand the factors and processes that shape people's risk perceptions. In our review, we propose that much of the research on risk perceptions to date can be grouped according to three dominant perspectives and, thus, approaches to study design; they are: the characteristics of hazards, the characteristics of risk perceivers, and the application of heuristics to inform risk judgments. In making these distinctions, we also highlight what we see as outstanding challenges for researchers and practitioners. We also highlight a few new research questions that we feel warrant attention.

KEY WORDS: affect heuristic; availability heuristic; hazards; naturalness; risk perception; values; worldviews

1. INTRODUCTION

Beyond simply accounting for what people fear and why, research on risk perceptions is important because of what it means for risk exposure, risk communication, and risk management. For example:

- The terrorist attack of September 11, 2001 not only *directly* killed and sickened Americans in New York, Pennsylvania, and Virginia; but, they also led—*indirectly*—to additional injuries and fatalities after the attack as more Americans, newly concerned about the security risks of air travel, opted for higher-risk long-distance travel by automobile instead (Gaissmaier & Gigerenzer, 2012; Gigerenzer, 2006).
- People who live in areas prone to high risk from natural hazards perceive themselves to be *physically* closer to the danger zone, and they are more inclined to support and undertake risk mitigation, if they have been previously evacuated ahead of a pending calamity. Meanwhile, other people living at an identical physical distance from the very same danger zones perceive themselves to be farther away, and are less likely to support and implement countermeasures, if they have not been previously evacuated (Tanner & Árvai, 2018).
- People who have directly experienced severe weather or climate-related phenomena tend to perceive higher risks from climate change, and tend to be more supportive of policies to mitigate its consequences for humans and the natural environment, when compared to people for whom the same phenomena are more *psychologically* distant (Spence, Poortinga, & Pidgeon, 2012). However, the strength of this relationship is tempered by factors such as economic status

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and political orientation (McDonald, Chai, & Newell, 2015).

Similar patterns emerge across a wide range of individual and societal hazards such as smoking (Weinstein, Marcus, & Moser, 2005), speeding (Brown, 2010), nuclear power (Greenberg & Truelove, 2011; Slovic et al., 1991), and genetic modification (Pidgeon et al., 2005). In sum, the manner in which people perceive risk is important because it influences individual behavior as well as the acceptance of—and commitment to—specific technologies, policies, and norms.

It is for this reason that researchers study risk perception, the factors that influence it, and what it means for all kinds of judgments and decisions. Indeed, the community of scholars and practitioners that follow this journal have committed themselves to improving our understanding of risk perception so that we may improve our capabilities when it comes to communication (Morgan, Fischhoff, Bostrom, & Atman, 2002), decision support (Bessette, Campbell-Arvai, & Arvai, 2016; Wilson, Arvai, & Arkes, 2008), and management (Renn, 1998). With this as backdrop, the aim of the present narrative review is to summarize and integrate our accumulated knowledge about risk perception, and to identify research gaps and needs that warrant future attention.

2. HAZARD CHARACTERISTICS AND RISK PERCEPTION

People drink alcohol and sunbathe but, at the same time, may be deeply concerned about pesticide residues well below the regulated levels in drinking water or electromagnetic radiation from mobile telephones. Why are people wary of hazards that experts agree do not cause significant harm, but are willing to expose themselves to hazards that result in very large numbers of fatalities every year? Part of the answer can be attributed to the reactions that are invoked by the specific characteristics of hazards themselves.

It is well known from psychometric research that certain characteristics of hazards render them more or less worrisome and, by extension, acceptable to people (Fischhoff, Slovic, & Lichtenstein, 1979; Starr, 1969). In the seminal—many would say, iconic—research on this subject (Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978; Slovic, 1987) a broad range of hazards were mapped in a two-dimensional factor space according to whether they were unknown and dreaded. Risks associated with a sense of "dread" are those that cannot easily be observed or controlled, lead to salient fatalities, are the consequence of involuntary exposure, and are catastrophic in their magnitude. Risks that are "unknown" tend to be novel, incompletely understood (or are *believed to be* incompletely understood) by respondents or science, and psychologically distant (Eyal, Liberman, & Trope, 2008) in that, their effects may be delayed in time or far away in space.

The results of the studies which draw on psychometric scaling suggest that, especially for lay respondents, the qualitative characteristics of a hazard may often be more important to them when assessing the potential severity of risks than more objective measures of mortality or morbidity (Kraus, Torbjorn, & Slovic, 1992). This explains why risks associated with technologies such as nuclear power, geoengineering, or genetic modification—all of which tend to be unknown and viewed with a sense of dread—are perceived by many lay people to be highly risky. Conversely, psychometric research explains why hazards such as alcoholic beverages or sunbathing—which tend not to be dreaded and well known—are seen as less risky.

Similar perceptions of technological and environmental risk according to the psychometric paradigm have proven to be robust internationally, including in China (Lai & Tao, 2003), Italy (Savadori, Rumiati, & Bonini, 1998), France (Karpowicz-Lazreg & Mullet, 1993), Poland (Goszczynska, Tyszka, & Slovic, 1991), and Norway (Teigen, Brun, & Slovic, 1988). It is noteworthy, however, that the individual characteristics that help to explain risk perception depend on the hazards that are selected. For example, when novel applications of nanotechnology were examined, trust in the technology and those responsible for its management had a significant influence on respondents' risk perceptions (Siegrist, Keller, Kastenholz, Frey, & Wiek, 2007). And, if societal risks such as racism, the erosion of moral values, or child abuse are included in the set of hazards examined, the degree to which a risk was disputed was seen as a more important characteristic compared with its newness (Bassarak, Pfister, & Bohm, 2017).

It is also noteworthy that psychometric research on risk perceptions also highlights a rather sharp disconnect between lay and expert respondents. Specifically, experts seem to treat the qualitive and affective (Slovic, Finucane, Peters, & MacGregor, 2002; Wilson & Arvai, 2006) characteristics of a hazard as less important for informing risk perceptions when compared with quantitative characteristics such as the

probability of exposure and the measurable magnitude of consequences (Savadori et al., 2004; Siegrist et al., 2007; Siegrist, Hubner, & Hartmann, 2018; Sjöberg, 1998; Slovic et al., 1995).

In sum, psychometric research is focused largely on how the characteristics of hazards may lead to different responses by individuals, and not on how differences between individuals may lead to different perceptions of risk. This semantic difference is most clearly reflected in the types of statistical analyses used when studying risk perceptions: for example, factor analysis for the former, and regression models for the latter.

Indeed, the importance of the characteristics of the individual *perceivers* (vs. the *hazards*) in risk perception point to an important shortcoming of many psychometric studies (Bronfman, Cifuentes, Dekay, & Willis, 2007; Siegrist, Keller, & Kiers, 2005; Sjöberg, 1996; Willis, DeKay, Fischhoff, & Morgan, 2005). That is, in many psychometric studies, aggregated data are the focus of analysis. In other words, what is effectively a three-mode data structure (i.e., hazards × rating scales × participants) is reduced to a two-dimensional matrix (hazards × rating scales) in order to facilitate a more straightforward analysis and interpretation of data. As a consequence, the main unit of analyses in many psychometric studies of risk is not the participants, but the hazards.

The ratings scales used in the psychometric risk paradigm have also been used to explain individual differences in risk perceptions; these studies focused on the "rating scales × participants" matrix in their analyses. For example, the degree to which exposure to a hazard is voluntary and delayed, and the hazard's magnitude and catastrophic potential account for a significant fraction of the model variance for risk perceptions of technologies like nuclear power or genetic engineering (Marris, Langford, & O'Riordan, 1998). In the food domain, controllability, inequalities in exposure, and the effect on children tend to account for a significant fraction of model variance (You & Ju, 2017). And, for terrorist attacks a significant fraction of the model variance for risk perceptions is accounted for by perceived severity, the number of people affected, and the likelihood of an attack (Mumpower, Shi, Stoutenborough, & Vedlitz, 2013).

The selection of the dimensions used to model risk perceptions within the psychometric paradigm often seem to make a great deal of intuitive sense; for example, researchers and practitioners interested in the characteristics of the perceiver may focus on dread as defined by the psychometric paradigm. However, the theoretical justification behind the selection of this factor is often either misguided (in that researchers claim to be studying individual characteristics when, in fact, they are studying the characteristics of the hazards) or missing entirely. In addition, one is often confronted with the challenge of disentangling the dimensions of risk studied in psychometric models—particularly as they relate to the factors of hazards that collectively are labeled "dread risk"—from what might also be accounted for by individual characteristics (such decision-making competence) which could be explained by dual-process theory (Slovic et al., 2002).

Thus, it is our position that psychometric research is useful for highlighting the relative positionality of risks encountered in day-to-day life but is hamstrung by low predictive and explanatory power with respect to the myriad psychological mechanisms behind *how* people perceive risk.

3. THE CHARACTERISTICS OF RISK "PERCEIVERS"

Perceivers of risk differ across a broad range of demographic characteristics, psychological traits, value orientations, and levels of domain-specific knowledge and understanding. These variables share some important commonalities: they manifest at the level of individuals, they tend to be rather stable over time, and each of them may influence risk perceptions. Thus, each has been studied extensively in order to help explain—and predict—individual differences in risk perceptions.

3.1. Demographic Characteristics

Sociodemographic variables such as gender, age, income, and education (in a generic sense) are rarely the main focus of contemporary risk perception research; instead they are used mainly as control variables. We know, for example, from a wide range of studies that gender tends to be only weakly associated with risk perceptions (Cullen, Anderson, Biscaye, & Reynolds, 2018; Olofsson & Rashid, 2011; Rivers, Arvai, & Slovic, 2010; Sjöberg, 2000). Similarly, studies have generally observed small or nonsignificant effects for age (Bearth, Saleh, & Siegrist, 2019; Nardi, Teixeira, Ladeira, & Santini, 2020; Olofsson & Rashid, 2011), income (Nardi et al., 2020; Sjöberg, 2000), and education (Bearth et al., 2019; Nardi et al., 2020; Olofsson & Rashid, 2011; Sjöberg, 2000).

However, this is not to suggest that there have not been revealing studies at the intersection of risk perceptions and demographic characteristics. For example, Flynn and colleagues (Finucane, Slovic, Mertz, Flynn, & Satterfield, 2000; Flynn, Slovic, & Mertz, 1994) focused on the interaction of risk perceptions with the gender of "white" and "nonwhite" (i.e., Native Americans along with Black, Asian, and Latino Americans). Their results revealed that white women perceived significantly higher levels of risk across a range of hazards when compared with their white male counterparts. This gender difference disappeared for nonwhite women and men, whose perceptions of risk were quite similar to each other, and to those of white women. Results such as these suggest that it is not gender or racial identity that drives risk perceptions as much as it is other psychological or cultural characteristics (Rivers et al., 2010).

3.2. Knowledge and Reasoning

As we note above, laypeople and experts frequently differ in their risk perceptions (Savadori et al., 2004; Siegrist et al., 2018; Sjöberg, 1998; Slovic et al., 1995). Based on the knowledge deficit model—which postulates that if laypeople were more knowledgeable, they would come to similar conclusions as experts—one might expect measures of general knowledge and risk perception to be correlated (Bubela et al., 2009).

However, it is currently in vogue among some members of the scientific community to claim that knowledge is not associated with people's risk perceptions (e.g., see Kahan et al., 2012). Many of these studies confound educational attainment (i.e., a high school diploma, a bachelor's degree, etc.) with domain-specific (or hazard-specific) knowledge. Alternatively, they focus on either self-reported knowledge about hazards (or the conditions leading to them) or, on knowledge that is of little to no relevance to a hazard in question (Kahan et al., 2012). We have observed that, if objective and domain-specific knowledge is measured in a reliable and valid manner, the correlation between knowledge and perceived risks is strong across varied domains, including climate change (Shi, Visschers, Siegrist, & Arvai, 2016; van der Linden, 2015), vaccines (Zingg & Siegrist, 2012), carbon capture and storage (L'Orange Seigo, Arvai, Dohle, & Siegrist, 2014), and synthetic chemicals (Saleh, Bearth, & Siegrist, 2019).

In addition to domain-specific knowledge, we can also consider the influence of reasoning ability on risk perception. Individuals with higher levels of scientific reasoning ability have been found to be more likely to perceive risk in a manner that is consistent with the scientific evidence regarding those risks. For example, people who score highly on the scientific reasoning scale perceive lower risks from vaccinations, which are well-known to the scientific community, and for which the scientific consensus is that the risk posed by them is small (Drummond & Fischhoff, 2017). On the other hand, for new and relatively unknown hazards, high scientific reasoning ability can lead to dampened risk perceptions perhaps because people feel there is an as yet insufficient scientific reason to be worried. Moreover, individuals with high scientific reasoning ability may nevertheless demonstrate low ability or willingness to deploy it based on their prior beliefs. Thus, the risk perceptions of people with greater scientific reasoning ability might not converge with the scientific consensus if they have already made up their minds that a hazard is either high or low risk (Drummond & Fischhoff, 2019).

Along similar lines, some individuals tend to be skeptical of science and may hold esoteric beliefs that lack a scientific basis. So-called "new age beliefs" are an example of this phenomenon, and they tend to be related to higher levels of risk perception (Sjöberg & af Wahlberg, 2002). Specifically, individuals who believe in the paranormal or divine powers (i.e., everything that happens is part of a grand plan) and who downplay the importance of analytic reasoning (i.e., the world would be a better place if more people relied on their feelings) also tend to possess elevated perceptions of risk for a wide range of hazards (including climate change, nuclear waste, and genetic engineering).

Beyond an individual's approach to scientific information, there is also evidence that certain judgments that may inform risk perceptions—for example, accurately forecasting the probability of a hazard's occurrence—are influenced by reasoning style. For example, actively open-minded thinking is a reasoning style during which people exhibit a tendency to weigh new evidence against a favored or preexisting belief, to spend enough time on a problem before locking in a judgment, and to consider alternative perspectives while arriving at one's own; research points to a strong predictive relationship between people with a with a high propensity for open-minded thinking and the accuracy of probability forecasts (Haran, Ritov, & Mellers, 2013).

Overall, the suggestion that the possession of, or more persistent attempts to acquire,

domain-specific knowledge does not influence risk perceptions seems misguided. While we agree with the idea that knowledge deficits are often disconnected from decision-making ability (Bessette, Wilson, & Arvai, 2019; Campbell-Arvai, Bessette, Wilson, & Arvai, 2018), the suggestion that domain-specific knowledge does not influence risk perceptions does not stand up to either logical or scientific scrutiny: The more one knows about the mechanisms underlying a particular hazard, the more predictable and highly correlated (with domain-specific knowledge) their risk perceptions tend to be. This finding has important implications for risk communication because, if we understand better how to increase relevant knowledge among people, we can help them to make more informed and better calibrated judgments about the various risks they face (Gigerenzer, Gaissmaier, Kurz-Milcke, Schwartz, & Woloshin, 2007).

3.3. Worldviews and Value Orientations

According to the cultural theory of risk, cultural worldviews—in other words, the pattern of beliefs and value orientations held by individuals in a collective, or by individuals as orienting dispositions that guide thoughts and behaviors (Mead & Métraux, 1954)—strongly influence risk perceptions (Douglas & Wildavsky, 1982). This theory postulates that people and collectives ascribe to one or more of a series of dominant value orientations—namely hierarchicalism, individualism, and egalitarianism—which, in turn, influence their perceptions of risk. In a seminal study (Dake, 1991), both societal risks (e.g., international threats, market failures, social deviance, environmental hazards) and risk perceptions in the generic domain of "technology" were found to be highly (though differentially) correlated with worldviews.

Subsequent research has expanded the set of value orientations that have been studied in the context of risk perceptions to include egoism, altruism, and biospherism (e.g., see de Groot & Steg, 2007). However, rather than reinforcing the findings of Dake (1991), these studies point to a murkier (and, sometimes, nonsignificant) relationship between worldviews and risk perceptions across a diverse set of potential hazards (Bouyer, Bagdassarian, Chaabanne, & Mullet, 2001; Brenot, Bonnefous, & Marris, 1998; Marris et al., 1998; Segrè Cohen, Love, Nace, & Árvai, 2020; Sjöberg, 2000, 2003).

Two of the routine contextual exceptions to the rather murky relationship between worldviews and risk perceptions are nuclear power and climate change. Studies conducted in the United States, Japan, and the Netherlands suggest that people's value orientations are associated with perceived risk and acceptance of nuclear power (de Groot, Steg, & Poortinga, 2013; Peters & Slovic, 1996; Tsujikawa, Tsuchida, & Shiotani, 2016; Whitfield, Rosa, Dan, & Dietz, 2009); for example, altruism and biospherism tend to be consistently negatively associated with perceived risks.

In the case of climate change, biospherism—and, to a lesser extent, egoism—was positively associated with perceived risks (Shi et al., 2016; van der Linden, 2015). Utilizing worldview measures in the tradition of Douglas and Wildavsky (1982), other studies have shown that people who identify strongly with hierarchicalism and individualism generally perceive lower risks associated with climate change when compared to people who do not ascribe to these value orientations (Kahan et al., 2012; Shi, Visschers, & Siegrist, 2015).

Along mechanistically similar lines, a more specific value scale that measures people's comfort with tampering with nature has recently been proposed (Raimi, Wolske, Hart, & Campbell-Arvai, 2020). Here, people who are strongly opposed to tampering with nature showed less support for technologies such as genetically modified organisms, pesticides, and geoengineering compared with people accepting tampering with nature.

3.4. Psychological Traits

The most influential model for measuring people's personality is the "five-factor model" (i.e., Big Five personality traits), which includes openness (e.g., one's degree of intellectual curiosity), conscientiousness (e.g., the tendency to show self-discipline and act dutifully), extraversion (e.g., the tendency to seek stimulation in the company of others), agreeableness (e.g., the tendency to be compassionate and cooperative towards others), and neuroticism (which is sometimes referred to as "emotional stability" and describes one's vulnerability to unpleasant emotions such as anger, anxiety, and vulnerability). This model characterizes individuals according to stable patterns of thoughts, feelings, and actions (McCrae & Costa, 1997). Of these five factors, only emotional stability was found to be weakly, but consistently correlated with perceived risk (Chauvin, Hermand, & Mullet,

2007; Sjöberg, 2003). For example, people who exhibit higher levels of emotional stability tend to perceive lower risk associated with a diverse set of hazards. Agreeableness and conscientiousness, by contrast, have occasionally been correlated (positively) with perceived risk; for example, in the context of unprotected sex and addiction (Chauvin et al., 2007).

People who exhibit high levels of anxiety may perceive more risks compared with people who have a low level of anxiety. It would seem plausible, therefore, if trait anxiety was correlated with perceived risks. However, only weak correlations were observed between trait anxiety and perceived risks (Bouyer et al., 2001; Leikas, Lindeman, Roininen, & Lahteenmaki, 2007).

Linked to personality traits, the propensity to trust others—including trusting individuals that are being met for the first time—tends to be negatively correlated with risk perceptions across a broad range of hazards (Siegrist, Gutscher, & Earle, 2005). People who tend to unconditionally trust people they have not had any interaction with perceived fewer risks associated with various technological and societal hazards compared with people who show a low level of general trust. The correlations observed are relatively low, however.

Looking beyond personality traits, certain odors (e.g., the scent of rotting food), visual cues (e.g., mold and discoloration), and tactile cues (e.g., slimy textures) may trigger disgust in individuals which, in turn, may influence risk perceptions. From an evolutionary perspective, these properties may have offered warnings of hazardous stimuli by evoking feelings of disgust (Curtis & Biran, 2001). However, the susceptibility to experience disgust towards such cues—which we call disgust sensitivity—varies across individuals (Hartmann & Siegrist, 2018) and has been shown to be associated with perceived risks. For example, people who oppose gene technology have been found to be more disgust sensitive compared with people who are more accepting of it (Scott, Inbar, & Rozin, 2016). Furthermore, people with higher food disgust sensitivity perceived more risks with novel food technologies (Egolf, Hartmann, & Siegrist, 2019) and various food hazards (Siegrist, Bearth, & Hartmann, 2020) compared with people having low food disgust sensitivity.

3.5. Optimism Bias

People often exhibit unrealistically high levels of optimism regarding a range of hazards (Weinstein, 1989). Specifically, research suggests that many people judge themselves to be less at risk for various hazards when they compare themselves with others (Shepperd, Waters, Weinstein, & Klein, 2015). For example, a recent study showed that even if risk and benefit information (as percentage range) about medical interventions was provided, participants showed positive optimism about the probability of experiencing side effects or benefits (Hanoch, Rolison, & Freund, 2019). This implies that patients may have unrealistic expectations regarding a treatment, even if numerical information is provided. Optimism bias has been studied extensively in the health domain, but it also manifests in other contexts such as risks from natural hazards such as hurricanes (Trumbo, Lueck, Marlatt, & Peek, 2011; Trumbo, Meyer, Marlatt, Peek, & Morrissey, 2014). This finding is in line with the observation that people tend to show less unrealistic optimism for events they have no control about (Shepperd et al., 2015).

3.6. Cross-Cultural Differences

Cultural differences in values and worldviews may result in different risk perceptions among people from different countries. It has been shown that a culture's position on the individualism–collectivism continuum influenced the risk perception of risky options (Weber & Hsee, 1998). For example, in China, people often perceive lower risk than their American counterparts even when considering identical stimuli.

People's exposure to hazards may also be different across countries. For example, food related risk perceptions were found to differ across hazards with Chinese participants exhibiting significantly higher risk perceptions compared with participants from eight other countries (Siegrist et al., 2020). Perceived low standards in the Chinese food production system could be the reason behind this result (Wu, Zhong, Shan, & Qin, 2013). There may also be differences in people's personalities across cultures; for example, the optimism bias in regard to risk perceptions caused by a tsunami or terrorism was found to be larger in a U.S. sample compared with samples from Argentina and Japan (Gierlach, Belsher, & Beutler, 2010).

A few studies included people from a large number of countries. One study with participants from 32 European countries found large differences for perceived risks and acceptance of gene technology across these countries (Gaskell et al., 2011). Large differences in risk perceptions have also been found

for risk perception of climate change in a study including data from 119 countries (Lee, Markowitz, Howe, Ko, & Leiserowitz, 2015). The reasons for these differences in risk perceptions are still largely unclear, however.

Overall, there have been only a relatively small number of studies that compare risk perceptions across countries (Gaskell et al., 2011; Lee et al., 2015; Shi et al., 2016; Siegrist et al., 2020). This is an important shortcoming because many risks such as genetically modified organisms and climate change—and, thus, the risk management strategies that may address them—cross international boundaries. Moreover, we are left with many questions about why we observe the large differences in perceptions as a function of nationality and culture. A simple explanation might be that people from different countries are interpreting or responding to rating scales differently (e.g., a propensity toward extreme responses in some cultures); if this is the case, some of the cross-national differences we observe may be artifacts.

However, we doubt that such a simple explanation would account for the kinds of differences in risk perceptions we have observed, and that we would expect going forward. In our view, we are still in the nascent stages of systematic cross-cultural research on risk perception, and we still do not fully understand the mechanisms behind observed differences in perceived risks across countries. Future research is sorely needed and should look beyond descriptive differences in risk perceptions across countries to include possible mechanistic explanations. Furthermore, future cross-national research should look beyond Europe and North America (and, to a growing extent, China and Japan) to also include a broader array of developed and—importantly—developing countries in Asia and Africa.

4. HEURISTICS

As we note above, people often lack in-depth knowledge to comprehensively evaluate many hazards. For example, studies show that laypeople often have only scant knowledge about technologies like gene technology (Connor & Siegrist, 2011a) or climate change (Shi et al., 2016). Therefore, lay people's evaluation of these (and other) technologies is often based on the use of heuristics, and not on more elaborate information processing (Slovic, Finucane, Peters, & MacGregor, 2004). This is also in line with the elaboration likelihood model (Meijnders, Midden, & Wilke, 2001; Petty & Cacioppo, 1986) which postulates that lack of knowledge or motivation results in the use of a peripheral route in which the use of simple heuristics are important.

Heuristics operate on the basis of what is known as attribute substitution (Kahneman & Frederick, 2005). That is to say, if a heuristic is used for the evaluation of a hazard, a target attribute (e.g., the objective probability of exposure to a hazard) that is not cognitively accessible is substituted with a seemingly related attribute that that can be accessed more easily (e.g., the number of concrete examples of the hazard that can be recalled).

A large set of heuristics that people may use when making decisions has been described elsewhere (Gigerenzer, 2008; Kahneman, Slovic, & Tversky, 1982; Montibeller & von Winterfeldt, 2015) and it is beyond the scope of this review to account for all of them here. Instead, we offer a brief overview of three heuristics that have been frequently used in the risk domain: the availability heuristic, the affect heuristic, and the natural-is-better heuristic.[1]

It is important to note that a reliance on a heuristic to inform risk perceptions does not imply that an individual is irrational, nor does it necessarily result in biased judgments. Specifically, a heuristic may lead to a judgment, or to a preference order, that adheres closely to the axiomatic principles of strict rationality (von Neumann & Morganstern, 1947); likewise, a heuristic may lead to an accurate estimate (e.g., of probability in the case of availability; see below) if the degree of calibration between the information and processes that underlie the heuristics are closely calibrated to reality.

4.1. The Availability Heuristic

When people use the "ease with which instances or occurrences can be brought to mind" to assess the frequencies or the probability of an event, they are relying on the availability heuristic (Tversky & Kahneman, 1974, p. 1127). For example, a person may assess the risk of cancer by thinking about how many people they know who died of the disease, or based on how often they hear (e.g., from friends or the media) that someone died of the disease.

Familiarity or salience may, however, influence the retrieval of events, and as a result in certain situations reliance on the availability heuristic may

[1] It has also been demonstrated that individuals use trust as a heuristic in the perception of risk. For a review, see Siegrist (in press).

result in biased decisions. The observed differences between subjective risk perceptions and the objective number of fatalities associated with a particular hazard could be linked to the availability heuristic (Lichtenstein, Slovic, Fischhoff, Layman, & Combs, 1978). However, Tversky and Kahneman (1974) were very unspecific about how availability should be operationalized (e.g., ease of retrieval, number of events recalled). If people had to decide which of two risks claim more lives, the number of deaths that occurred in their family, friends, and acquaintances due to a hazard was the availability measure that best predicted people's judgments (Hertwig, Pachur, & Kurzenhauser, 2005). The same measure of availability was also used in another study, and the results of this study suggest that the availability heuristic better predicts people's estimated statistical mortality rates of a broad set of hazards compared with the affect heuristic (Pachur, Hertwig, & Steinmann, 2012).

Several studies have examined the impact of the availability heuristic on risk perception related to natural hazards such as flooding (Keller, Siegrist, & Gutscher, 2006; Siegrist & Gutscher, 2006; Tanner & Árvai, 2018). In one study, participants indicated whether neighbors or acquaintances were harmed by flood (Siegrist & Gutscher, 2006). Results of this study suggest that people who could remember flooding events perceived to be more at risk in regard to flooding where they lived compared with people who could not remember such events. This relationship could even be observed when the objective risk level was controlled for. Risk information provided to participants was also influenced by participants' experiences with flood (Keller et al., 2006). The same probability information about the occurrence of a flood was perceived as riskier if participants had prior flood experience.

Along similar lines, people who experienced a flood and have been forced to evacuate, judged themselves to be physically closer to a high risk area compared with people who have not experienced a flood first hand (Tanner & Árvai, 2018). Similar effects were observed for hazards as diverse as domestic fire, terrorist attacks, or earthquakes (Knuth, Kehl, Hulse, & Schmidt, 2014). People who had experienced the event before showed higher risk perceptions compared with people not having such experience.

The availability heuristic seems also to influence perceptions of risk regarding climate change (Demski, Capstick, Pidgeon, Sposato, & Spence, 2017). Furthermore, perceived increases in wet-weather-related and hot-weather-related events were associated with climate change beliefs (Taylor, de Bruin, & Dessai, 2014).

The recalled events measured in the studies examining the availability heuristic are almost always affective tagged. Therefore, it may not be fully clear whether people relied on the availability or on the affect heuristic. Only one study we are aware of examined which one of the two heuristics best explained people's risk judgments (Pachur et al., 2012).

4.2. The Affect Heuristic

As we note above, the affect heuristic assumes that the affective meaning evoked by a hazard influences its risk and benefit perceptions (Finucane, Alhakami, Slovic, & Johnson, 2000). Slovic and colleagues (Slovic et al., 2004, p. 314) defined this heuristic as follows: "All the images in people's minds are tagged or marked to varying degrees with affect. The affect pool contains all the positive and negative markers associated … with the images."

People rely on this affect pool when they make judgments, and different approaches for examining the influence of affect on risk perception have been used. Slovic and colleagues (Slovic, Finucane, Peters, & MacGregor, 2007) proposed, for example, the imagery technique to measure people's affect. In this method, a word or a sentence is presented to participants, and they have to provide the first thought or image that comes to their mind. After the elicitation of the associations, participants rate them on a scale ranging from negative to positive. This technique has been used to measure people's affect related to nuclear power (Keller, Visschers, & Siegrist, 2012; Peters & Slovic, 1996), gene technology (Connor & Siegrist, 2011b), or mobile phone base stations (Dohle, Keller, & Siegrist, 2012). Results of these studies suggest that the valence of the spontaneous associations are associated with people's risk perceptions and acceptance of a technology. They also provide some information about the content of the associations that have the strongest impact on the negative or the positive affect associated with a hazard.

In other studies, study participants have been directly asked about their feeling of dread, worry, and anxiety, or about the degree of valence they associate with a hazard (Al-Jader, Parry-Langdon, & Smith, 2000; Lee & Lemyre, 2009; Nakayachi, 2013; Pachur et al., 2012; Prati, Pietrantoni, & Zani, 2011; Raue et al., 2019; Siegrist & Sütterlin, 2014; Terpstra, 2011;

Wilson & Arvai, 2006; Zhao, Rosoff, & John, 2019). Perceptions of risk regarding a broad set of hazards have been examined in these kinds of studies; they include risks as varied as self-driving cars (Raue et al., 2019), pandemic influenza (Prati et al., 2011), terrorism (Lee & Lemyre, 2009), and tornadoes (Zhao et al., 2019).

The affect heuristic may result in biased judgments (Nakayachi, 2013; Siegrist & Sütterlin, 2014). One of these studies suggest that information about a specific risk increased fear not only about a specific risk, but also about the whole risk category to which it belonged (Nakayachi, 2013); specifically, elevated risk perceptions regarding genetically modified foods spilled over leading to elevated risk perceptions about food safety in general.

The affect heuristic may also lead people to ignore information about risks that might otherwise be useful when formulating risk perceptions (Sunstein, 2003). For example, if the context in which a particular hazard is situated leads to strongly negative feelings of arousal, it may draw people's attention away from data that would otherwise help them to characterize the risk as low. To illustrate this point, Wilson and Arvai (2006, 2010) exposed people to hazards that one might encounter in a park setting: risks from wildlife overpopulation and risks from nonviolent crime. Wildlife overpopulation elicited neutral affective responses, whereas nonviolent crime elicited strongly affective responses. However, data about the objective magnitude of these two hazards clearly highlighted greater dangers to human and environmental health from the former. Regardless of the degree of difference between the high affect/low risk and low affect/high risk contexts, people routinely perceived higher risk in the scenarios that elicited a strongly negative affective response.

It is important to note that use of the affect heuristic as described by Slovic and colleagues (Finucane et al., 2000; Slovic et al., 2004; Slovic et al., 2007) in risk perceptions research poses some challenges in terms of its predictive specificity (Gigerenzer, 2008). For example, is it the most negative or positive affective associations that influence people's risk perceptions, or is it the average of all associations? Moreover, questions about the directionality of causation may also be raised. Specifically, it is difficult to rule out the possibility that it is risk perceptions that drive affective responses and not *vice versa* as is implied by many studies.

Overall, the affect heuristic can often be used as a *post hoc* explanation for results obtained in a study and as a consequence, the explanatory power may be limited. Therefore, additional studies that merely show that affect associated with a hazard and its risk perception are correlated may be of limited value. More helpful in the future are studies that will, for example, examine specific associations that evoke positive or negative affect, and in what situations the affect heuristic results in biased versus high-quality (i.e., internally consistent; see Bessette et al., 2019) judgments and decisions.

In some studies, specific emotions evoked by a technology were measured (Merk & Ponitzsch, 2017; Midden & Huijts, 2009). It remains questionable, however, whether people can feel delight or happiness with stratospheric aerosol injection as measured in one of these studies (Merk & Ponitzsch, 2017). Based on introspection one has serious doubts that such emotions are experienced. Furthermore, these studies have not included measures of affect (negative–positive). It remains unclear, therefore, whether measuring specific emotions would have provided the same results. This lack of clarity underscores the importance of testing new measures against the findings from established (and validated) ones.

4.3. The Natural-is-Better Heuristic

In Western countries there is strong preference for naturalness, and nature is perceived as benevolent (Scott & Rozin, 2020). The term "natural" evokes almost exclusively positive emotions in people (Rozin, Fischler, & Shields-Argeles, 2012). Experimental studies suggest that *processes* that lead to certain outcomes are more important in terms of how people make judgments about qualities such as risk than the outcomes themselves (Campbell-Arvai, 2019; Rozin, 2006). In other words, processes that involve human interventions are often seen as reducing naturalness, even if the outcomes are no different from what would have occurred naturally. Discounting the positive effect of human interventions and the negative effect of natural processes has been labeled as natural-is-better heuristic (Siegrist & Hartmann, 2020).

People seem to rely on the natural-is-better heuristic when evaluating food and they perceive natural foods to be healthier, better tasting, and better for the environment (Roman, Sanchez-Siles, & Siegrist, 2017). It has been suggested that genetically

modified food is perceived as a violation of naturalness, and that this may be an important reason for the lack of acceptance of this technology (Scott, Inbar, Wirz, Brossard, & Rozin, 2018).

The natural-is-better heuristic implies that the same outcome is differently evaluated when it is caused by humans compared with nature. The process seems to be important, and not the outcome. Therefore, this heuristic may result in biased judgments (Campbell-Arvai, 2019; Hoogendoorn, Sütterlin, & Siegrist, 2020; Siegrist & Sütterlin, 2014). For example, people who believed that climate change is caused by humans perceived the suffering among people during the hurricanes that hit the United States in 2017 as higher compared with people who believed that natural processes causes climate change (Hoogendoorn et al., 2020). In other words, the perceived cause of a hurricane influenced how bad the death of people was perceived and how much suffering was attributed to these people.

In line with the natural-is-better heuristic, synthetic chemicals are much more negatively perceived compared with chemicals of natural origin (Saleh et al., 2019; Siegrist & Bearth, 2019). This perception results in a biased risk perception of cleaning products with an "eco" label on it (Bearth, Miesler, & Siegrist, 2017). For example, people evaluated an "eco" drain cleaner as much safer compared with a regular drain cleaner, despite the two products containing very similar ingredients.

The natural-is-better heuristic also applies to risks in nonhuman settings. In a vignette experiment, participants were asked to evaluate the suffering of 1,200 birds which were killed in an oil spill (Siegrist & Sütterlin, 2014). When the accident was caused by humans, participants rated the suffering to be significantly higher compared with an accident caused by nature. The very same negative outcome is evaluated more negatively when caused by humans. Similarly, in a study about risks to ecosystem health, respondents viewed identical photographs of forest scenes that were framed as the aftermath of natural or anthropogenic disturbances. Restored forests following natural disturbances were judged significantly more positively across a broad range of ecosystem qualities than the identical scenes following an anthropogenic disturbance. And, disturbances that were natural in origin were, retrospectively and prospectively, more acceptable than anthropogenic disturbances; tying this to our previous discussion of worldviews, these results were most strongly observed for individuals who identified strongly with biospheric values (Campbell-Arvai, 2019).

These examples illustrate the potential of the natural-is-better heuristic to cause biased judgments. Instead of focusing on the risks of a technology or a product, the focus is on who has caused it. Weighting the process stronger than the outcome is certainly not the best strategy for reducing the risks we face.

Concerns about tampering with nature (Sjöberg & af Wahlberg, 2002) are related to the natural-is-better heuristic. Geoengineering, gene technology, pesticide use, and cloning are technologies that are predominantly perceived as tampering with nature (Raimi et al., 2020). People differ in how tampering with nature a technology is perceived, and it has been shown that support for carbon dioxide removal techniques is influenced by perceptions of tampering with nature (Wolske, Raimi, Campbell-Arvai, & Hart, 2019). Similar findings were reported in a study that examined lay people's perceptions of ten different climate engineering technologies (Jobin & Siegrist, 2020). Perceived tampering with nature was highly correlated with perceived risks associated with these technologies.

4.4. The Importance of Heuristics

Different theoretical frameworks such as the elaboration likelihood model (Petty & Cacioppo, 1986) or the heuristics and biases paradigm (Kahneman et al., 1982) emphasized the importance of adopting a kind of cognitive shorthand in many judgment and decision-making contexts. It follows naturally that many studies of risk perception would follow suit. There is considerable overlap between the various heuristics, however. For example, the salient events invoked during the use of the availability heuristics often possess affective meaning. The same is true for the natural-is-better heuristic which is also associated with affective meaning. It is, therefore, not always clear which heuristics participants in the studies described above relied on.

There is no doubt that heuristics play an important role for people's risk perceptions. It is still unclear, however, in which situation people rely on what heuristic. Furthermore, future studies should, as emphasized by Gigerenzer (2008), describe heuristics in a way that testable hypothesis can be deduced, and

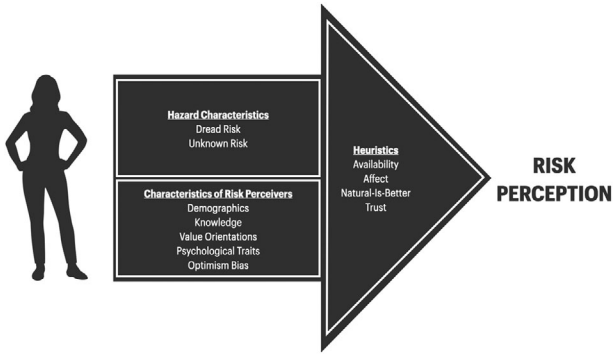

Fig 1. Factors influencing people's risk perceptions (adapted from Fig 2 in Siegrist & Hartmann, 2020).

heuristics should not be used as *post hoc* explanations for study findings.

5. CONCLUSION

From its inception, the journal *Risk Analysis* has been an important outlet for research on risk perceptions. We found that we could group the research under three general approaches (Fig. 1). One approach has been to focus on how participants perceived various characteristics of a hazard, and how this influenced perceived risks. A second approach has been to identify characteristics of participants that are correlated with, or predictive of risk perceptions. And, a third approach focuses on the various heuristics that have been proposed to better explain the process behind how people formulate risk perceptions.

In terms of the first approach, which focuses on how the characteristics of hazards account for differences in risk perceptions, the psychometric paradigm has provided us with useful insights into why various hazards evoke different levels of perceived risk. The hazard factors referred to as "dread risk" and "unknown risk" strongly influence how a hazard is evaluated. For lay respondents, for example, the number fatalities or the probability of a negative event are less important compared with affective or qualitative hazard characteristics. Many studies utilizing the psychometric paradigm as an underlying framework to explain risk perceptions produced similar results. Additional studies aiming at replicating the findings reported in the initial psychometric work (Slovic, 1987), therefore, offer few new theoretical insights. However, this framework can be fruitful when it comes to accounting for risk perceptions of novel hazards. Furthermore, if nonaggregated data are used, such studies may provide insights in how people differ in their risk perceptions and what factors may explain these differences.

The second approach to research on risk perception focuses on the characteristics individual perceivers of risk as the driving forces behind their judgments. The optimism bias, for example, has been found to strongly influence participants' risk perceptions (Weinstein, 1989) in a negative direction; that is, for many personal risks, people tend to view the risks they face as lower than the same risks faced by others. This bias poses a challenge for risk communication and management in that, if few people feel at greater risk than they would attribute to others, few people would feel motivated to pay attention to risk communication or to take action to mitigate risk.

In addition, while the Big Five personality traits tend to be at best only weakly correlated with people's risk perceptions, the importance of knowledge and worldviews is clearer. Our review shows that, for hazards like climate change, both knowledge and worldviews are important factors that influence people's risk perceptions. Moreover, controversies about the importance of knowledge and worldviews have more to do with how these variables are measured. Thus, it is our view that future research should focus to a lesser degree on the question of whether these two constructs are important, and to a greater degree on the situations in which greater levels of knowledge, or where significant cultural differences, lead to differential responses—in terms of perceptions and management—to different risks.

The third approach focuses on heuristic processes that underlie the formulation of risk perception. That heuristics may play an important role in risk perception (and that they can be a source of bias) is well-known (Kahneman et al., 1982). There are several heuristics to consider in the context of risk perceptions. Our review centered on three: the availability heuristic, the affect heuristic, and the natural-is-better heuristic.

We are not suggesting here that all heuristics are important in terms of their influence on all risks (nor all kinds of judgments or decisions). There is clear support, however, that in certain situations these heuristics play an important role for risk perception. Yet, open questions remain in the context of risk perceptions as to which heuristic people rely on and in what hazard contexts? For example, when is trust, or availability, or affect more important for shaping people's risk perceptions? In our view, more research

is needed that directly compares the predictive power of different heuristics when it comes to the formulation of risk perceptions. And, beyond a question of purely academic interest, we would also benefit from a better understanding of the conditions that lead to the use of different heuristics (and their accompanying biases) so as to better inform efforts aimed at risk communication and decision support (Arvai, 2014).

How the three clusters of variables depicted in Fig. 1 interact with each other warrants more attention in future studies. For example, do people with more domain-specific knowledge about a hazard rely to lesser degree on heuristic judgments compared with people with less? Likewise, why do value orientation seem to be relevant for some hazards, but not for others; is it possible to identify the hazard characteristics that moderate the association between people's values and risk perceptions? These are but a small handful of questions that could be taken up in future research at the intersection of hazard characteristics, the characteristics of risk perceivers, and the psychological processes that underly judgment and decision making.

Overall, the importance role of risk perceptions in people's subsequent judgments and decisions must not be taken for granted. However, future research should focus on the relationships between risk perceptions and other variables that influence judgment, choice, and—ultimately—behavior. For example, research focused on the acceptance of novel technologies explicitly assumed that it is influenced by people's risk and benefit perceptions (Bearth & Siegrist, 2016; Siegrist, 2000). This causal model has been criticized, however, because preexisting general attitudes may simultaneously influence perceived risks/benefits and acceptance (Scott et al., 2018). Future research must, therefore, examine whether risk perceptions causally influence the acceptance of hazards or risk management measures or whether these are only spurious correlations caused by another variable (e.g., affect). Moreover, the situations in which risk perceptions are posited to be an important predictor of judgment, choice, and behavior should be examined using not only survey studies, but also experimental studies that further illuminate causality.

We end this review with an important caveat: Though we have focused on three approaches to studying risk perceptions, we do not wish to imply that they are exhaustive. We have too much respect for the diversity of research methods in our field to assume that there is only one way to conceptualize 40 years of research on risk perceptions.

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