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Developing a Broadly Applicable Measure of Risk Perception

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Decades of research identify risk perception as a largely intuitive and affective construct, in contrast to the more deliberative assessments of probability and consequences that form the foundation of risk assessment. However, a review of the literature reveals that many of the risk perception measures employed in survey research with human subjects are either generic in nature, not capturing any particular affective, probabilistic, or consequential dimension of risk; or focused solely on judgments of probability. The goal of this research was to assess a multidimensional measure of risk perception across multiple hazards to identify a measure that will be broadly useful for assessing perceived risk moving forward. Our results support the idea of risk perception being multidimensional, but largely a function of individual affective reactions to the hazard. We also find that our measure of risk perception holds across multiple types of hazards, ranging from those that are behavioral in nature (e.g., health and safety behaviors), to those that are technological (e.g., pollution), or natural (e.g., extreme weather). We suggest that a general, unidimensional measure of risk may accurately capture one's perception of the severity of the consequences, and the discrete emotions that are felt in response to those potential consequences. However, such a measure is not likely to capture the perceived probability of experiencing the outcomes, nor will it be as useful at understanding one's motivation to take mitigation action.

KEY WORDS: Affect; consequences; emotion; measurement; risk perception

1. INTRODUCTION

As scholars in the field of risk and decision making, we are often asked what is the "best" way to measure risk perception. This is a question that is surprisingly hard to answer given what seems to be widespread agreement on how to define the concept. From a disciplinary perspective, we would argue that risk perception research finds its home in behavioral decision science, in particular the field of judgment and decision making. Although these are the origins of risk perception from a psychometric standpoint, the concept is now widely used in research ranging from health sciences to communication to engineering. These origins track back to the 1960s and 1970s, when Daniel Kahneman, Baruch Fischhoff, Paul Slovic, and other scholars identified a disconnect between public perceptions of risk and technical assessments of risk, and began to study the influence risk had upon decision making (Kahneman & Tversky, 1979; Slovic, 1987; Slovic, Fischhoff, & Lichtenstein, 1982). Their research demonstrated that while technical assessments focus largely on the probability of experiencing particular negative consequences, there are different factors that lead an individual to perceive a particular hazard

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as risky. Specifically, those hazards perceived as particularly risky by the public tend to be both dreaded and unknown. The dread factor was identified by Slovic as the driving force in determining what hazards would be perceived as risky (Slovic, 1987). Specifically, Slovic found that hazards perceived as uncontrollable, inequitable, involuntary, and potentially catastrophic tend to be perceived as risky, which may or may not reflect the reality of such hazards from a probabilistic standpoint. For example, terrorism is a hazard that many individuals fear, even though the probability of experiencing a terrorist attack is very low (Sunstein, 2003). However, individuals have little control over whether or not they are exposed to such an attack, and exposure is often inequitable while the consequences are both emotionally vivid and catastrophic. Other hazards that pose a greater risk to public health and safety over time are often ignored, as they are not particularly salient in terms of their dreaded characteristics (e.g., cancer caused by unhealthy diets, climate change as a result of energy consumption) (Sunstein, 2007).

Due in part to early research on the psychometric paradigm, countless studies have since focused on this idea of "risk as feelings" (Loewenstein, Weber, Hsee, & Welch, 2001; Sjöberg, 2000; Slovic, Finucane, Peters, & MacGregor, 2004). As a result, there is an explicit recognition that intuitive assessments of risk give greater weight to the characteristics of the consequences that one might experience, as opposed to the probability of experiencing those consequences. Despite this tendency for the literature to converge on the importance of the affective or emotional component of perceived consequences, many measures of risk perception still focus primarily on more deliberative components such as the perceived likelihood of experiencing the hazard, or one's likely exposure. For example, studies may use questions such as "How likely is it that you will experience the hazard?" or "How often does the hazard occur where you live?" (see e.g., Kern et al., 2014; Knuth, Kehl, Hulse, & Schmidt, 2014; So & Shen, 2016). Other researchers have focused their measures more exclusively on the nature of the consequences, keying into Sandman's work where perceptions are operationalized as a function of the consequences, multiplied by the outrage that the individual feels about those outcomes (Sandman, 2004). Such studies include questions like "How serious do you feel the negative consequences of X are to you personally?" (Martin, Bender, & Raish, 2007). While others have gone even further to focus their measurement of risk almost exclusively on the affective components, capturing the worry, fear, anger, and other discrete negative emotions associated with the hazard (e.g., "When you think about *X* for a moment, to what extent do you feel worried? Fearful? Anxious?") (Ferrer, Klein, Persoskie, Avishai-Yitshak, & Sheeran, 2016).

One recent study attempted to identify an ideal measure of risk perception in the context of disease and health behaviors (Ferrer et al., 2016). The authors argue that current conceptions of health risk consist of either just a deliberative dimension (i.e., likelihood of experiencing a negative outcome), or an additional affective or experiential dimension (i.e., degree of worry about the outcome, or perceived vulnerability). Their study identified that a tripartite factor structure, including all three dimensions—deliberative, affective and experiential—was the best fit across three different diseases (cancer, heart disease, and diabetes). Their affective dimension captured a combination of worry and distinct emotions, while their deliberative dimension captured the likelihood of developing the disease. Their experiential dimension was less clear in its focus, including measures of concern, vulnerability, vividness, and probability of getting the disease. They further found that each dimension explained unique variance in health behaviors, and that finer-grained, more specific measures of risk perception are particularly important for select, critical audiences (such as those having been diagnosed with a disease).

Others have suggested that current approaches to measuring risk perception are both limited in comparability and not informed by the latest developments in psychometrics. Cano and Salzberger (2017) argue that Rasch Measurement Theory (RMT) may be the most promising tool for creating risk perception measures around high-stakes issues like tobacco use. In RMT, an individual's level on a latent construct and the level of multiple items on the same construct can be estimated independently, but still compared to one another (Acton, 2003). In comparison to classical test theory, this approach poses more stringent assumptions about the model in question by recognizing that a construct is not just the function of the items chosen to measure it. Cano and Salzberger (2017) also point out that tobacco product risk perception measures are often just one item, focusing on the health consequences, while failing to consider the full range of potential consequences (e.g., social, financial, etc.). We believe that this disparity in measurement is not unique to tobacco use, and that such a range in measurement rigor could be found in a number of other contexts.

Perhaps due to the widespread use of this construct across hazards and disciplines, there is to date no standardized measure of risk perception. We would contend that few of the existing measures are wrong per se, but that a standardized and accepted measure of risk perception would go a long way toward measuring risk perception both accurately and consistently across the range of disciplinary applications. This would in turn increase our ability to compare perceptions of risk across hazards, and across time. Advancement in this latter area would address a key obstacle in the field of risk communication; the challenges associated with applying lessons learned in one risk context to another. As a result, the overall goal for this research was to identify the dimensions of risk that are relevant to assessing risk perception across a multitude of domains (e.g., natural hazards, health behaviors, etc.). The specific objectives of the research are then threefold. First, to conduct a review of the literature to identify the range of risk perception measures currently being used in survey-based research. Second, to use this review to identify the different dimensions of risk perception being assessed, and the range of items being used to assess those dimensions, so that we could select a set of representative items for testing. And third, to assess this standardized set of items across a range of hazards representing the bulk of the domains explored in risk research, with the goal of identifying a measure that will be broadly useful for assessing perceived risk moving forward.

2. LITERATURE REVIEW

2.1. Review Methods and Analysis

We conducted a literature review in the spring of 2017 to catalog the ways investigators have measured risk perception. While the terms "severity" and "consequences" are readily understood, other terms such as "probability," "exposure," and "vulnerability" are used inconsistently and operationalized in more diverse ways (for a list of terms and definitions relevant to risk perception, see Table I). Published studies were found using both Google Scholar and university library databases. Articles included in this review were limited to those published in English and were sorted by both date and number of times cited to primarily return recent studies of impact. No emphasis or priority was given in regards to journal or discipline. The review began broadly, searching first for studies containing the terms "risk perception" and "perceived risk" in the title, followed next by articles that contained those terms in the keywords. Additional articles were gleaned from citations related to risk perception in the studies of this first round. Next, more targeted searches were conducted, looking for risk perception studies applied to specific contexts (i.e., health, environment, weather, etc.). All studies that reported a measure of risk perception were included in the review and scale ranges and labels were recorded when provided.[3] Studies where the measures focused on a particular characteristic of the risk itself or what type of risk a hazard presented (e.g., a controllable risk, a desired risk), were excluded. For example, we excluded a study measuring the controllability of recreation-based risk because it was narrowly focused on particular characteristics of a risk but not perception per se (Rickard, 2014), but included studies where controllability items were included as explicit measures of risk perception (Ho, Shaw, Lin, & Chiu, 2008; Mann & Wolfe, 2016; Niens, Strack, & Marggraf, 2014; Zhou, Song, & Tian, 2016). The collection of studies continued until there was a high amount of repetition in the items used to operationalize risk perception. The goal of our review was not to be fully inclusive of the studies measuring risk perception in the literature, but to capture the range of measures currently in use. Therefore, this review is to be regarded as a convenience sample and not a systematic review.

A simple coding scheme was created to reflect the three major approaches researchers use to measure risk perception. The first approach uses general items asking the individual to gauge how risky a hazard or activity might be. This is typically done with a single item measure (e.g., "How risky is *X*?"), without recognition of the various dimensions that compose risk perception. The second approach consists of items or scales that independently measure the two generally accepted dimensions of risk: the perceived or actual probability of experiencing a risk and the severity of the consequences that result. The final approach focuses solely on the affective component. These items typically measure discrete negative emotions (i.e., worry, fear, etc.). A separate category was created for studies that employed more than one of these methods, so that each study was placed in a single category. Any study that employed a different

[3] Scale ranges and labels available upon request.

Table I. Terms and Definitions for Risk-Perception-Related Constructs.[a]

Term	Definition	Example
Hazard	The entity that poses a particular likelihood of negative consequences	*Natural hazards include earthquakes, tsunamis, wildfires, and severe weather.*
Exposure	The number of people/things impacted by a hazard The base rate for stochastic hazards	*The number of people exposed to secondhand smoke has decreased in the last decade.* *An average of 1,224 tornadoes touch down per year across the United States.*
Risk	The possibility a negative outcome will occur as a result of exposure to a hazard	*There is always a risk of injury when downhill skiing.*
Probability	The quantified likelihood that a hazard occurs	*There is a 0.3% chance of being in a car accident on a 1,000-mile trip.*
Vulnerability	The relative degree of risk contingent on personal exposure to the hazard	*Children are more vulnerable to the risks associated with poor air quality than adults.*
Consequence	The negative outcomes to something of value given exposure to a hazard	*The potential consequences of hurricanes range from minor damage to total destruction and loss of life.*
Severity	The extent or magnitude of the consequences experienced	*While the probability of a terrorist attack is low, the consequences are very severe.*

[a]These are our best definitions of the terms, with examples to provide context of how they may be used. However, an exhaustive discussion of such definitions can be found at http://www.sra.org/sites/default/files/pdf/SRA-glossaryapproved22june2015-x.pdf

method of measuring risk perception was coded in an inductive manner, allowing new methods of categorization to emerge from the literature review. Two members of the research team coded all the studies independently, with any differences discussed and the final coding agreed upon.

2.2. Review Results

A total of 81 studies were initially collected and catalogued before encountering high amounts of repetition in the specific items used to measure risk perception. Of these 81, nearly 75% of them (60) fit into the *a priori* categories of *general*, *probability & consequences*, and *affect*. Two new categories were created inductively: *risk versus benefits* (eight studies) and *probability only* (eight) to capture the remaining studies. A total of 16 studies used a combination of two approaches to measure risk perception (Table II; see Table AI for a full list of the studies summarized).

The most common approach in our sample was the use of *general* measures that do not address the specific underlying dimensions. This unidimensional approach to risk was used in 40% (32) of the studies reviewed (e.g., Nordeng, Ystrøm, & Einarson, 2010; Safi, Smith, & Liu, 2012; Toma & Mathijs, 2007). Nearly all of the measures in this category were phrased in some variation of "How risky is X?" or "Indicate the level of risk X presents to Y." In a few instances, terms such as "dangerous" or "safe/unsafe" were used in the place of "risk" (e.g., Salameh et al., 2014).

The remaining studies included in our review were evenly split in their approach. Ten studies (12%) measured risk perception solely from an *affective* point of view (e.g., Grasmück & Scholz, 2005; Spence, Poortinga, & Pidgeon, 2012; Walker, Mertz, Kalten, & Flynn, 2003). Without exception, all of these studies used measures of "concern" or "worry" regarding a risk. Seven studies (9%) measured risk perception following the traditionally accepted definition of risk, including separate items to measure *probability & consequences* (e.g., Matthew et al., 2015; Rosen & Kostjukovsky, 2015; Yang, 2016). Probability was assessed with one or more items asking about the "chances," "likelihood," or "probability" of realizing a risk. Two studies used the term "vulnerability" when referring to the chances of realizing a risk (De Zwart et al., 2007; Martin et al., 2007). While consequences were measured in a variety of ways, the most common method pertained to the "severity" of the consequences, or how "serious would it be" if the risk was realized. One study asked the likelihood of a series of increasingly severe risks as a way of integrating the two constructs (O'Connor, Bard, & Fisher, 1999).

Fourteen studies (17%) measured risk perception in a manner that fell outside of the original coding scheme: *probability only* and *risk versus benefit*. Eight studies (10%) used single or multiple items that solely focused on the perceived probability of

Table II. A Summary of Studies by the Measures Used to Operationalize Risk Perception; Inductively Created Categories Were Created After Reviewing the Entire Sample; Studies Were Obtained via Convenience Sampling; Therefore, the Proportions of Measures Used Do Not Reflect the Entire Population of Risk Perception Studies

	Deductively Created			Inductively Created		Multiple Categories			
	General	*Prob. & Conseq.*	*Affect*	*Risk v. Benefit*	*Prob. only*	*General & Affect*	*Prob., Conseq. & Affect*	*Prob. & Affect*	Total
# of studies	32	7	10	8	8	2	9	5	81
% overall	40%	9%	12%	10%	10%	2%	11%	6%	100%

Note: The full list of references for the studies summarized in Table II are included in the Online Appendix.

a risk occurring without measuring the severity of the resulting consequences (e.g., Peacock, Brody, & Highfield, 2005; Weinstein et al., 2007). Five of the studies in this category were focused on health, where the risk was experiencing an injury or contracting an illness (essentially confounding the hazard and consequences). Eight studies (10%) operationalized risk perception by having respondents weigh the risks and benefits of something against each other (e.g., Gaskell et al., 2004; Micklewright et al., 2015; Overdevest & Christiansen, 2013). With one exception (see Anderson, Brossard, Scheufele, Xenos, & Ladwig, 2014), perceived risks and benefits were measured with separate items. It should be noted that the Domain Specific Risk Taking Scale (DOSPERT) (Blais & Weber, 2006), used by three studies, was included in the *risk versus benefits* category as the DOSPERT items measure propensity to take risk in order to gain the expected benefits.

We originally intended to classify both *probability only* and *risk versus benefit* under the *general* category. After reviewing the literature, however, it was clear that both of these approaches differed from the *general* measures. Studies in the *risk versus benefit* category measured more than one dimension of risk perception, which set them apart from the other unidimensional measures. While the *probability only* measures were also unidimensional, they focused on a single component of risk perception, whereas the measures in the *general* category were a generic measure of the construct as a whole.

A total of 16 studies (19%) employed some combination of two approaches when measuring risk perception. Nine studies (11%) combined measures of *probability & consequences* and *affect* (e.g., Leiserowitz, 2005, 2006; Rundmo & Sjöberg, 1998). Three of these studies measured discrete emotions (the extent to which, for example, a respondent felt fearful, anxious, worried, etc.) in addition to holistic concern (Demuth, Morss, Lazo, & Trumbo, 2016; Mann & Wolfe, 2016; Trumbo et al., 2016) and two contained items measuring the psychometric paradigm dimensions (i.e., the extent to which a risk is dreaded, controllable, unknown) (Niens et al., 2014; Zhou et al., 2016). Five studies (6%) combined *probability only* measures with *affect* (e.g., Armas, Ionescu, & Posner, 2015; Ram & Chand, 2016; Rübsamen et al., 2015). Finally, two studies combined the use of *general* and *affect* measures (Nuccio et al., 2015; O'Neill, Brereton, Shahumyan, & Clinch, 2016). The studies that combined probability only items with affect items illustrate how some measures, while theoretically incomplete, may still be effective. These studies did not include items to measure consequences, but one could consider the affective impact of the perceived likelihood of a risk occurring as a proxy for the expected, or dreaded, severity of the consequence.

We consider those studies using separate items for probability, consequences, and affect as measuring risk perception in the most complete and theoretically accurate manner. The former items quantify the perceived magnitude of the risk, while the latter measure its psychological impact on the individual. As one example, Leiserowitz (2006) operationalized climate change risk perception with an index of items measuring concern, severity, and the perceived likelihood of various impacts at the local to global level. In some studies this clarity and rigor came at the expense of survey length and participant cognitive load, but this was not always the case. Some studies in the *general* category actually contained more items without addressing any of the underlying constructs of risk perception.

In sum, nearly two-thirds of the studies included in our literature review measured risk perception in a manner that would be considered theoretically incomplete, using items that were either too broad or focused too narrowly on an individual component of risk perception. Keeping in mind that most of the studies included the term "risk perception" or "perceived risk" in the titles, how risk perception is operationalized is consequential for the conclusions being drawn, as well as how risk research is used by those outside the discipline. We contend that although the concept of risk perception was formulated within the domain of judgment and decision making, its use as a measure is now widespread across disciplines, perhaps contributing to the inconsistency we see in measurement.

3. MEASUREMENT SURVEY

3.1. Survey Methods

The next step in our study was to develop a survey instrument to assess the dimensional structure of risk perception, identify how such a structure might vary across different types of hazards, and assess the predictive power of our risk perception measure at explaining protective behavioral intentions. We hypothesized that risk perception (1) is multidimensional and (2) will carry the same dimensional structure across hazards. However, (3) the dimensions of risk reflected in a general measure of risk perception for each hazard will vary and (4) a multidimensional measure will better predict self-protective behavior than a unidimensional measure.

We recruited 300 participants using the online panel service Prolific Academic in August 2017. Participants were U.S. residents over 19 years old who were compensated $1.30 for their participation. Four participants were removed from the final sample because they answered only a handful of the questions posed in the survey. The final sample of 296 had a mean age of 32.5 years and was 40.2% female. Participants were asked to respond to a series of risk perception items, repeated across four separate hazards. These hazards were chosen to represent a wide variety of risk contexts that differ by source of the hazard, and target of the consequences. Specifically, we began by identifying three sources of a hazard—oneself (for behavioral hazards), society (for technological hazards), and the environment (for natural hazards). The consequences associated with these three types of hazards were, generally speaking, targeted at the self (for personal hazards) or at the self and others (for societal and environmental hazards). Using this initial set of categories, we identified a set of hazards as examples of these attributes (Table III).

From these three categories, we then selected the following four hazards: extreme weather events, contaminated waterways, walking late at night in a dangerous neighborhood, and eating potentially contaminated food while traveling (Table IV). Extreme weather events are natural hazards that affect both the individual and others. To increase the applicability and salience of extreme weather events, we asked respondents what kind of extreme weather (flooding, high-wind events, wildfires, or earthquakes) was most common in their area. All subsequent items about "extreme weather" focused specifically on that particular event.[4] Contaminated waterways are a technological hazard that again has a diffuse set of risk targets. In contrast, walking late at night in a dangerous neighborhood poses risks to the individual only. Walking in a dangerous neighborhood and eating potentially contaminated food were chosen to specifically differentiate between personal behavioral hazards that had impacts on one's safety versus health. Many hazards that share these characteristics are widely studied in the literature (i.e. smoking, recreational risks, etc.); however, there is potential for them to differ systematically due to the nature of their consequences.

The specific risk perception items chosen represented the main categories that emerged from our literature review (general risk perception, affect, probability, consequences) (Table V). Other concepts that are critical to assessing technical risk, such as exposure and vulnerability, did not consistently appear in our literature review, but may need to be accounted for more explicitly in future studies. In order to more accurately test the generalizability of these items across hazards it was important that each

[4] One-way ANOVAs were conducted to assess differences across each of the four weather hazards for general risk, intentions, and the scaled risk dimensions. There were no significant differences except for the measures of general risk ($F(3,287) = 6.05$, $p = 0.001$). Subsequent independent samples T-tests showed this to be driven by a significantly higher mean for wildfire than all three other weather hazards ($p < 0.05$; $M = 4.31$ compared to $M = 3.65$, $M = 3.78$, $M = 3.80$ for flood, wind events, and earthquakes, respectively). All subsequent CFA and regression analyses were run both including and excluding the 38 cases of individuals who selected the wildfire hazard with no substantive loss of fit for the CFAs (in fact the fit was better in many cases) and no substantive differences in the interpretation of the regressions (i.e., no changes in significance of predictors, large shifts in R^2, etc.). Results of the analyses with the wildfire cases removed are available by request from the corresponding author.

Table III. A Typology of Hazards by Source, Type, and Target of Consequences

Hazard Source	Type of Hazard	Consequences	Examples
Personal	Behavioral	To me	Unprotected sex, smoking, skydiving, driving under the influence
Societal	Technological	To me & others	Nuclear power, GMOs, pollution, nanotech
Environmental	Natural	To me & others	Extreme weather, wildlife disease, radon, mold

Table IV. The Four Identified Hazard Domains and Identified Attributes Related to Source, Type, Target of the Consequences, and Focus on Health Versus Safety

Hazard	Source	Type	Target	Risk Category
Extreme weather	Environmental	Natural	Self+others	Property/safety
Contaminated waterways	Societal	Technological	Self+others	Health
Walking in dangerous neighborhood	Personal	Behavioral	Self	Safety
Eating potentially contaminated food	Personal	Behavioral	Self	Health

Table V. Suggested Risk Perception Items Used in the Unidimensional (*General*) and Multidimensional (*Affect*, *Probability*, *Consequences*) Models Organized by the Literature Review Categories with Standardized Factor Loadings from the Confirmatory Factor Analysis

Category	Items	Weather	Waterways	Neighbor	Food
General					
G1	How risky is/are X?	–	–	–	–
Affect (i.e., concern/emotion)					
E1	How concerned are you (if at all) about X?	0.855	0.821	0.848	0.812
E2	When you think about X for a moment, to what extent do you feel fearful?	0.868	0.851	0.912	0.863
E3	When you think about X for a moment, to what extent do you feel anxious?	0.887	0.846	0.857	0.853
E4	When you think about X for a moment, to what extent do you feel worried?	0.903	0.920	0.904	0.827
E5	Considering any potential effects that X might have on you personally, how concerned are you about X?	0.835	0.799	0.868	0.827
Probability					
P1	How likely is it that *X will occur*/[you will do X] this year where you live?	0.937	0.927	0.898	0.921
P2	I am confident that *X will not occur*/[I will not do X] this year where I live (Reverse)	0.709	0.757	0.725	0.566
P3	*How often do X occur where you live?* [How often do you X?]	0.604	0.753	0.814	0.697
Consequences[a] (i.e., severity)					
S1	If I did experience X, it is likely that it would negatively impact me	0.743	0.734	0.826	0.713
S2	If I did experience X, it would have a severe effect on me personally*	0.851	0.933	0.861	0.940

Note: Italicized text used for the environmental hazards; bracketed text used for the behavioral hazards.
[a]A third item: "How severe are the impacts of X where you live to you personally" was originally included but removed because the residuals correlated with all 5 items from the affect scale.

Table VI. Risk Mitigation Intention Items Organized by Hazard

Extreme Weather Events	
EW1	I am interested in receiving more information about weather hazard X in my local community.
EW2	I intend to search for information about preparing for weather hazard X and safety protocols in the future.
EW3	In the future, I intend to prepare my home for weather hazard X.
EW4	I intend to obey future warnings to seek shelter or evacuate during weather hazard X.
EW5	I intend to develop and maintain a plan for how I will respond to weather hazard X in the future.
Contaminated Waterways	
CW1	I am interested in receiving more information about contaminated waterways in my local community.
CW2	I intend to search for more information about safety protocols in the event that local waterways are potentially contaminated.
CW3	I intend to search for information about my impact on local waterways.
CW4	I intend to use filtered or bottled water to avoid drinking polluted water in the future.
CW5	I intend to change my behaviors to reduce my future impact on local waterways.
CW6	I intend to donate to a local organization involved in cleaning up polluted waterways.
CW7	I intend to volunteer for a local organization involved in cleaning up polluted waterways.
Walking in a Dangerous Neighborhood	
DN1	I am interested in receiving information about how to stay safe when walking late at night in a dangerous neighborhood.
DN2	I intend to plan a route to get where I'm going so I don't have to walk late at night in a dangerous neighborhood.
DN3	If I would have to walk late at night in a dangerous neighborhood in order to get where I wanted to go, I intend to get a ride or take a cab instead.
DN4	If I could not get a ride and would have to walk late at night in a dangerous neighborhood in order to get where I wanted to go, I would cancel my trip.
Eating Potentially Contaminated Food	
CF1	I am interested in receiving information about the possible contamination of food wherever I travel.
CF2	I plan on taking medicine with me wherever I travel in the event that I get sick from eating potentially contaminated food.
CF3	I intend to plan my trips so that I never have to eat potentially contaminated food.
CF4	If I had to choose between eating potentially contaminated food and not eating at all, I would not eat.

Note: Responses were scaled from 1 (strongly disagree) to 5 (strongly agree).

participant respond to the same set of items for every hazard. Therefore, items were carefully worded to apply across hazard domains. Hazards were presented in the same order to each participant; however, the items were presented in a random order within each hazard.

Participants were also asked to respond to several items for each hazard indicating their intentions to take a variety of protective actions (Table VI). These items were created explicitly for this study by the authors. While a change in risk perception alone does not lead to mitigation or self-protective behaviors, behavior change is a common end goal of risk communication. We therefore included behavioral outcome variables to serve as a validity check (Weinstein, Sandman, & Roberts, 1991).

3.2. Survey Analysis

We analyzed our data through multiple methods. First, we conducted a series of confirmatory factor analyses using the Lavaan package version 0.5-23.1097 for the R statistics program version 3.4.2 (Rosseel, 2012; Team RC, 2014). These analyses assessed the fit of our proposed model against other potential models that could account for our data. Second, we conducted a multiple groups confirmatory factor analysis to assess whether the best-fitting model fit similarly across all four hazard domains. We used the criteria of metric invariance across groups, requiring that the loadings of items on their respective factors should be similar across the four hazards. Third, we used a series of regression analyses to determine which factors from our best-fitting model could account for variance within one generic risk item (i.e., "How risky is X?"). We used the generic item as the dependent variable, and mean scores on the subscales for each dimension as predictors. This would provide a clue as to which dimensions of risk perception are actually captured in a unidimensional and generalized measure of risk perception, and the extent to which these dimensions representing this construct might vary across domains or hazards. Fourth, we conducted a series of hierarchical regression models to predict mitigation intentions using just the general risk perception item and then adding in the indices of the dimensions derived from the best-fitting model. This allowed us to assess whether measures of the proposed dimensions can more accurately predict behavioral intentions over a general risk perception measure and, if so, to what degree.

3.3. Survey Results

3.3.1. H1: Risk Perception Is Multidimensional

Our original conception of the items based on prior literature would require a three-factor model comprising (1) measures of concern and emotion related to the hazard (*affect*), (2) one's exposure to the hazard and/or the probability of that hazard occurring (*probability*), and (3) severity of the consequences of the hazard (*consequence*). We did not include the general risk perception items in the factor analysis, as we wanted to separately explore the relationship between the general items and the specific dimensions. Additionally, we wished to compare our three-factor model to other theoretically relevant models that might organize our items in different ways to investigate our first hypothesis that risk perception is multidimensional. We therefore tested our three-factor model against a single-factor model with all items loading onto a single dimension of risk perception, and a two-factor model that separated the items into experiential (*affect*, *consequence*) and deliberative (*probability*) dimensions. We ran confirmatory factor analyses to test the fit of each model for each hazard using robust maximum likelihood estimation (an estimation method that helps to account for biases in chi-square tests against data that are not distributed normally). All factors were freely allowed to correlate with one another in the models. The three-factor model (*affect, probability, and consequence*) had an acceptable fit across all four hazard domains. Despite the fit not being excellent, it was shown to have considerably improved fit over the other models (Table VII). Specifically, point estimates for the RMSEA fell between 0.039 and 0.076 while comparative fit indices (CFI) ranged between 0.959 and 0.988, indicating reasonable fit. The standardized factor loadings for each of the CFA models are displayed in Table V.[5] These results support our first hypothesis that risk perception is multidimensional, as the multidimensional model better accounted for responses to the items than a single- or even two-factor model.

3.3.2. H2: Risk Perception Will Carry the Same Dimensional Structure Across Hazards

To investigate our second hypothesis that the dimensional structure and factor loadings of our items will be consistent across hazards, we transformed the data set by treating participants' responses on the 10 risk items for each hazard as a separate group in a confirmatory factor analysis (CFA). Because participants answered equivalent risk items for each hazard, we were able to treat responses to each hazard as a different group of responses to the same 10 items. As a result of the transformation, we were left with responses to the 10 risk items across four "groups" defined by the hazard that the participant was responding to at the time for each set of responses. We allowed the factor loadings to vary freely between groups in one version of the model while we constrained them to be equal across groups in another and compared the fit of the two models. We assessed fit based on a <0.01 change in the comparative fit index (CFI) between the constrained and unconstrained models; a commonly used cutoff for determining measurement invariance

[5]There was evidence of correlated residuals, suggesting some shared variance between items across factors not accounted for by the structure imposed by the CFA. Correlated residuals between one item, "How severe are the consequences of X where you live to you personally," and a variety of other items were found across all four hazards in similar patterns. Coupled with the "double-barreled" phrasing of the item (i.e., references to both geographical and personal relevance), we did not feel that this item was appropriately capturing a subjective judgment of the severity of consequences to the person. As a result, we removed this item from the analyses. The remaining correlated residuals help to explain why the fit indices for some of the hazards are not excellent. Given that the items were constrained in their design to be applicable to all four hazards, it is reasonable to expect that each item may be interpreted slightly differently for each hazard, contributing to these correlations. Residual correlation tables are available on request from the corresponding author.

Table VII. Model Fit Statistics Across Hazards

	Model Fit				
	Chi square	df	p	CFI	RMSEA (90% CI)
Weather events					
Affect/probability/consequence	83.48	32	<0.0005	0.959	0.076 (0.059–0.093)
Experiential/deliberative	139.14	34	<0.0005	0.916	0.105(0.090–0.121)
Single factor	282.762	35	<0.0005	0.801	0.159 (0.145–0.174)
Contaminated waterways					
Affect/probability/consequence	66.4	32	<0.0005	0.975	0.061 (0.043–0.080)
Experiential/deliberative	152.34	34	<0.0005	0.914	0.110 (0.095–0.126)
Single factor	406.89	35	<0.0005	0.73	0.193 (0.178–0.207)
Walking in a dangerous area					
Affect/probability/consequence	72.68	32	<0.0005	0.974	0.066 (0.048–0.085)
Experiential/deliberative	147.55	34	<0.0005	0.927	0.107 (0.091–0.124)
Single factor	427.08	35	<0.0005	0.747	0.196 (0.182–0.211)
Eating contaminated food					
Affect/probability/consequence	45.5	32	0.057	0.988	0.039 (0.004–0.062)
Experiential/deliberative	152.02	34	<0.0005	0.899	0.112 (0.095–0.129)
Single factor	317.93	35	<0.0005	0.757	0.171 (0.155–0.187)

between groups (Hirschfield & Von Brachel, 2014). The results of the grouped CFA analysis revealed that the CFI for the unconstrained three-factor model across groups was 0.973 while the CFI for the model constrained to identical factor loadings was 0.968. This represents a change in CFI of around 0.005, which is less than the recommended cutoff of <0.01. This suggests that the items that make up the scale load similarly onto the same factors across hazards. Specifically, constraining the factor loadings to be identical across hazard domains did not significantly reduce the fit of the model. As a result, we find support for our second hypothesis that the dimensional structure does not vary by hazard.[6]

3.3.3. *H3: The Dimensions of Risk Perception Represented in a General Risk Perception Measure Will Vary by Hazard*

To investigate our third hypothesis, we used the proposed measures of each of the three dimensions to predict responses to the general risk perception item. Cronbach's α for each of the relevant scales can be found in Table VIII. Given the exploratory nature of the research and that the items were selected to represent as broad a spectrum as possible, several of the values for α are relatively low. While this indicates that the combination of specific items chosen may not represent the best possible scales for assessing these dimensions across all of the hazards, the reliability of the items was sufficient for creating an averaged index of intention and dimensions of risk for each hazard domain. We then standardized each of the indexed variables for ease of interpretation. The resulting variables were all significantly correlated with one another. Specifically, the affect and consequence variables had positive correlations ranging from 0.663 to 0.744 across the hazards (all $p < 0.05$).[7] The probability variable correlated positively with consequence and affect for

Table VIII. Cronbach's α for the Final Response Scales

	Affect	Consequence	Probability	Intentions
Weather	0.939	0.772	0.756	0.852
Waterways	0.927	0.815	0.845	0.898
Neighborhood	0.943	0.830	0.840	0.777
Food	0.926	0.804	0.759	0.766

[6] This is to say that we meet the criteria for metric invariance or equal loadings between groups. We do not meet the criteria for scalar invariance, suggesting that the intercepts may be significantly different between groups. This is unsurprising given that we would expect the hazards to differ systematically in the degree of likelihood, consequences, and affective content associated with them.

[7] While we believe affect and consequence to be distinct but conceptually related, correlations this high do elicit concerns about multicollinearity. However, regressions predicting general risk perception and intentions from the three risk dimensions showed tolerances universally above 0.48 (VIF = 1.09–2.06). Multicollinearity statistics are available on request.

extreme weather, contaminated waterways, and potentially contaminated food (ranging from 0.127 to 0.285 and 0.317 to 0.336, respectively, all $p < 0.05$). Interestingly, for walking in a dangerous neighborhood, probability was negatively correlated with both affect and consequences (–0.131 and –0.203, respectively, both $p < 0.05$). This may not be surprising considering that it is likely that our participants have a high degree of control over whether they walk in a neighborhood they would consider unsafe. As a result, we would expect their likelihood of exposing themselves to such a neighborhood to be negatively related to feelings of concern or fear and judgments of severe consequences related to such areas.

The results of the regression analyses predicting general risk perception from the various dimensions support the idea that the affect and consequence dimensions are particularly important in explaining people's intuitive risk perception (Table IX). These two dimensions explained a significant and unique amount of the general risk variance across all hazards, while the probability dimension was only significant in the context of extreme weather events and walking alone in a dangerous neighborhood. However, in these instances, the probability measure was still considerably less influential than either affect or consequences. These results provide further support for Hypothesis 1, that a subjective assessment of risk is multidimensional (composed of, at least, an affective judgment and the severity of the potential consequences). These results partially support Hypothesis 3 that the dimensions represented in a general measure of risk perception will vary for different hazards. Specifically, affect and consequences are consistent across the hazards, but probability varies.

3.3.4. *H4: A Multidimensional Measure of Risk Perception Will Predict Self-Protective Behavior Better than a Unidimensional Measure*

To investigate our fourth hypothesis, we compared models of behavioral intentions to mitigate risk from each hazard. We began by using only the general risk perception item as a predictor in a unidimensional model, followed by a multidimensional, hierarchical model drawing on each of the three dimensions in turn (Tables X and XI). The results show a large increase in R^2 when a multidimensional measure of risk perception (starting with the affect and consequence dimensions) is used, supporting Hypothesis 4 (Table X). Interestingly, this suggests that while probability rarely seems to matter much in determining a person's subjective judgment of the riskiness of a hazard, it plays an important role in whether or not a person plans to protect himself or herself from certain hazards. Table XI shows the coefficients for the two models of behavioral intention, again showing that the affect and consequence dimensions are dominant in determining behavioral intentions; however, probability often contributes some unique predictive power.

4. DISCUSSION

Overall, we found support for our first hypothesis that risk perception is a multidimensional construct. The three-factor model fit the group of items often used to measure risk perception better than any of the other models tested, including the unidimensional measure that combined all of the items together under a single construct. This is consistent with prior assessments of risk perception in the health domain (Ferrer et al., 2016), although we would label our three dimensions affective, consequential, and probabilistic, given the items used in our analysis. We also found support for our second hypothesis that the dimensional structure will be the same across hazards. However, we found only partial support for our third hypothesis that different dimensions of risk would be more or less important across hazards for determining the general measure of risk perception. The strongest effects on general risk perception were consistently from the experiential end of the equation (affect and consequences), with the effects of probability being varied and insignificant for two of the four hazards. Finally, we found clear evidence supporting our fourth hypothesis that our more nuanced multidimensional measure of risk perception better predicted self-protective behavioral intentions across hazards, which is also consistent with earlier studies (Ferrer et al., 2016).

While our results indicate that a general, unidimensional measure of risk is not particularly valid or reliable, in our review of the literature we found that almost half of the studies relied on this simplistic approach (Table II). A minority of studies measured affect (by itself), or included measures of both affect and consequences, the primary drivers of variation in our general measure (i.e., up to 50%). Further, several studies used probability measures only as a measure of risk perception, whereas our results identify this dimension as much less critical to individual's subjective assessments of risk. While our results

Table IX. Regression Results Predicting a Unidimensional Measure of General Risk Perception for Each Hazard from the Three Dimensions

	Predictors			
	Affect	*Probability*	*Conseq.*	*Total R^2*
Weather	0.356***	0.113*	0.226***	0.319
Contaminated waterway	0.341***	−0.007	0.330***	0.352
Dangerous neighborhood	0.381***	−0.127**	0.379***	0.553
Contaminated food	0.429***	0.028	0.330***	0.448

*Significant at $p < 0.05$, **significant at $p < 0.01$, ***significant at $p < 0.001$.

Table X. The Variance Explained (R^2) from a Model Predicting Intentions from a Unidimensional, General Risk Perception Item Only Versus a Hierarchical Model Including the Three Dimensions; The Change in R^2 for Each Stage of the Hierarchical Model Is Indicated in Parentheses

	Unidimensional Model	Multidimensional Model		
	General	Affect	Consequence	Probability
Weather	0.212***	0.430 (+0.430***)	0.442 (+0.12*)	0.454(+0.012*)
Waterways	0.126***	0.522 (+0.522***)	0.526 (+0.004)	0.526 (+0.000)
Neighborhood	0.285***	0.336 (+0.336***)	0.414 (+0.078***)	0.436 (+0.022*)
Food	0.236***	0.472 (+0.472***)	0.513 (+0.040***)	0.532 (+0.019**)

Table XI. Standardized Regression Coefficients from a Model Predicting Intentions from a Unidimensional, General Risk Perception Item Only Versus a Hierarchical Model Including the Three Dimensions

	General	Affect	Consequence	Probability
Weather	0.456***	0.533***	0.132*	0.118*
Waterways	0.370***	0.689***	0.074	0.002
Neighborhood	0.535***	0.329***	0.333***	−0.153**
Food	0.487***	0.636***	0.198***	−0.151**

*Significant at $p < 0.05$, **significant at $p < 0.01$, ***significant at $p < 0.001$.

suggest that probability is not as important a component of holistic risk perception as affect or consequence, it certainly is in regards to risk assessment, and perhaps to individual assessments of whether or not to take protective action.

Along this vein, our literature review highlighted the problematic nature of interchangeable terms like probability, exposure, and vulnerability. This made it difficult to identify items from the literature to use in this current assessment. Perhaps one way to clarify these concepts going forward would be to break probability down into a function of exposure and vulnerability. Specifically, one could measure probability as a function of the likelihood of a hazard occurring in a particular area (i.e., exposure), and in a way that exposes the population of interest to potential negative effects (i.e., vulnerability). The risk perception literature does not clearly account for these components, presenting an opportunity to better explore a more complete measure of probability moving forward. The consequences are much more clearly represented in the literature as a function of the perceived personal impact of those negative effects (i.e., severity) and the outrage embedded in that potential experience (i.e., affect). In other words, although we did not assess exposure and vulnerability explicitly in our study, perhaps the most accurate equation for measuring risk perception would characterize probability as a function of exposure and vulnerability, while consequences is a function of severity and emotion:

$$Risk = Probability\ (Exposure + Vulnerability) \times Consequences\ (Severity + Affect).$$

Finally, the total variance explained in our general and unidimensional measure of risk using the affect, consequences, and probability dimensions ranged from ~30% to 60%. This means that, depending on the hazard, there is the possibility that a general risk perception item is capturing other dimensions not assessed in our study. Similarly, neither the general nor the more specific dimensions of risk perception fully explain behavioral intentions. Although some of this unexplained variance is likely due to error variance, there are other potential explanations. Improving our measures of probability as outlined above may help to explain additional variation in intention, while accounting for the likely interaction between affect and consequence may better explain our general measure of risk perception and intention (e.g., representing consequence as a mediator of the relationship between affect and general risk perception or intention). This may also be where advanced psychometric techniques could improve our understanding of variations in risk perception across a population. Perhaps some of the unexplained variance can be attributed to differences in personality or ideology that interact to explain variation in the items used to assess perception. For example, the hazard of contaminated waterways may be one where individual risk perceptions are heightened based on one's degree of environmental concern, or biospheric value orientations. We also chose to focus on the personal nature of a hazard and its consequences, given the evidence that personal and localized risks are more critical to understanding risk perception (Chandran & Menon, 2004; Fujita, Eyal, Chaiken, Trope, & Liberman, 2008; Leiserowitz, 2006; Spence et al., 2012). If we include the consequences of exposure to a hazard to society more generally, or to nature, we may capture some of the individual differences in concern about the impact of a hazard on others broadly defined. This could increase the accuracy of our measurement for risks that are particularly problematic for others but not oneself (see Leiserowitz's [2006] measure as an example of such an approach).

In sum, although multidimensional measures of risk may be more accurate from a measurement standpoint and more useful at explaining mitigation intentions, using a simple more general measure of risk perception, (e.g., "*How risky is X?*") may be appropriate in some instances. Specifically, this simple measure may be appropriate when risk perception is just used as a control variable in an analysis, or where the experiential dimensions represented by the general measure are sufficient for the purposes of the research. In instances where one is measuring risk perception as a means of explaining protective action, then a multidimensional measure is necessary. At a minimum, the chosen measure in this case must capture the affective responses of the respondents, and their perception of the severity of the consequences. However, when deciding whether to take action, individuals may be asking both "How threatening is this?", which is reflected by experiential assessments of affect and consequence, as well as "How likely am I to have to deal with this?", which is reflected by the probability assessment. This more deliberative assessment of probability may help a researcher further understand one's likelihood of taking protective action for certain hazards.

5. LIMITATIONS AND FUTURE RESEARCH

One potential limitation of this research is that it was designed as a measurement study, not a systematic review of risk perception measures or a meta-analysis of the effect of risk perception on behavioral intentions. As a result, we did not review all of the risk perception studies that exist, and could have overlooked individual items that may have increased the variance explained in our general measure of risk perception, and in our measures of mitigation intention. Although we may not have captured the best possible items to represent each dimension for each hazard individually, we believe we captured the range of dimensions in use at a conceptual level in survey-based quantitative methods. It may also be that the dimensions or specific items may vary when one explores other quantitative measures of risk perception (e.g., real-time response methods) or even qualitative assessments (e.g., talk-aloud protocols).

We suspect that turning our attention to the psychometrics of measuring risk perception may help to increase our understanding further. Specifically, as pointed out by Cano and Salzberger (2017), future research could use our dimensions of risk, while testing a greater range of individual items within a particular domain, but also assessing how much of a latent construct a person has to have in order to endorse a particular item at a given level. Similarly, we focused on the possibility of harm to the self, and not to others. It is possible that responses to our items would vary if consequences to society in general or to nature were considered. Future research could assess the applicability of the risk perception measures presented here for a hazard occurring at different spatial and temporal scales to better tease out perceptions of risk related to the self versus others. However, we also expect that sensitivity to these types of consequences may vary by the individual differences highlighted previously (e.g., political ideology, environmental values, etc.).

In addition, the four hazard domains in our study were chosen to vary across characteristics we thought were initially important (e.g., hazard source and target of consequences). However, future studies could delve further into this variation by varying the hazard with a more explicit focus on the timing of consequences. As is clear from the extant research on discounting (Frederick, Loewenstein, & O'Donoghue, 2002) and psychological distance (Spence et al., 2012; Trope & Liberman, 2003), the temporal nature of the consequences certainly impacts the weight that people may place on different risks. For example, when the consequences are immediate, as in the case of extreme weather, nuclear meltdowns, and driving under the influence, we would expect that the severity of the consequences and the outrage experienced might increase. For consequences that are delayed and perhaps more uncertain, as in the case of smoking, eutrophication, and climate change, we would expect that the severity of the consequences may be perceived as lower, and the outrage perhaps more a reflection of individual factors such as political ideology (as is the case for climate change) (McCright & Dunlap, 2011).

6. CONCLUSION

In sum, this study represents a first step toward identifying a multidimensional measure of risk perception for use across different types of hazards. Future measures of risk perception should incorporate the experiential components of risk, namely, affect and the severity of consequences. Measures of probability should be included for understanding behavioral intensions, but further work is needed to better differentiate exposure and vulnerability when thinking about how individuals perceive the likelihood of experiencing negative consequences. Moving toward standardization in how risk perception is measured will be necessary to unify the many disciplines with interests in this topic, and to allow for comparisons in perceived risk across space and time. This will be particularly critical as we continue to see risk sit at the core of the wicked problems that require multiple disciplines to work toward a solution.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table AI. The Table Below Mimics Table II from the Text, But Includes the Full List of Studies from the Literature Review Within Each of the Designated Categories