Driving into Danger: Perception and Communication of Flash-Flood Risk

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ABSTRACT

Floods, particularly urban flash floods, frequently disrupt traffic, constraining mobility and exposing motorists to danger. Flood risk managers educate the public on the dangers of driving through flooded roadways, yet losses to life and property continue to occur. This study integrates cultural psychology and risk perception theory to explore how cultural and situational factors influence motorists' behavior during flash floods. Flood risk managers in Tucson, Arizona, collaborated in the development of a questionnaire mailed to local residents in 2007. Self-reported levels of trust, self-efficacy, social incorporation, and situational factors were analyzed with respect to whether respondents stated that they have or have not driven through a flooded roadway. Respondents demonstrate complex reasoning when confronted with flooded roadways, rather than simple or consistent risk-taking or risk-avoidance behaviors. Participants indicate high levels of trust in official warning messages and share information about floods within their social networks, highlighting the success of education campaigns. However, flood conditions are not always clear, so motorists seek additional sources of information and weigh the dangers against other situational factors on a case-by-case basis. Factors that influence respondents' decisions include the prior successful crossing of other vehicles, presence of signs and barricades, presence of passengers, risk of personal injury or damage to the vehicle, and the availability of flood-related information. The results also show that individuals who know how to avoid floods, including by asking others for advice, are less likely to enter flooded roadways, and thus communicating further instructions will empower more motorists to avoid danger.

1. Introduction

Risk perception research has been used to investigate how people respond to hazard information and how risk managers might alter warning messages or dissemination methods to stimulate a wider practice of what they consider the appropriate response. In most cases, risk managers attribute failure to respond appropriately to irrationality or lack of information (Douglas 1992; Frewer 2004; Jasanoff 1998; Slovic 1999). Thus, risk communication research and practice have focused on tailoring the message until people understand and cease engagement in risk-taking behaviors (Douglas 1992; Kasperson and Kasperson 2005). Such an approach does not typically account for the context that shapes how different groups are exposed to risks, what other information might be available for decisions, and what options are considered acceptable.

This study contributes to a growing literature that examines motorist behavior upon encountering floodwaters, applying cultural theory to examine some motorists' apparent disregard for flood warning messages. The streets in semiarid Tucson, Arizona, are usually dry, but, during brief but intense rains, localized street flooding can be excessive and hazardous. The increased frequency of these events during the rainy season allows residents to develop complex strategies for evaluating flood danger and deciding how to proceed.

Flood risk managers from city and county agencies collaborated in the development of a survey mailed to Tucson residents to identify which factors would influence motorists' decisions upon encountering flooded roadways (see the selected survey questions in the online supplemental material). The survey addressed

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cultural factors known to affect risk perception, as well as how these factors predict participants' past or typical behavior in flash-flood scenarios. These factors include (i) trust in hazard managers; (ii) use of social networks to share information; and (iii) self-efficacy, or how confident people feel in their ability to handle both extreme events and ordinary life. The survey also addressed the effects of situational factors on participants' decision-making and behavior. The information gathered in this project provides insight into risk-taking behavior as it relates to culture and situational context, including the reasons why individuals drive into flooded roadways even when they are aware of the potential danger and how they combine official and unofficial sources of information to aid in decision-making.

2. Background

Floods are among the leading causes of weather-related mortalities. Studies that examine flood-related mortalities typically consider (i) environmental conditions, such as location, time of day, type of flood, road surface, and presence or absence of warnings; (ii) type of event, such as flash flood, tropical cyclone, or river flood; (iii) demographics, especially age and gender but sometimes profession, ethnicity, income, and education; and (iv) activities and behavior, with special attention to whether the victim intentionally (active) or unintentionally (passive) entered floodwaters. The key results of these mortality studies are summarized below.

In the United States and elsewhere, a large proportion of flood fatalities relate to vehicles, with some drowning within the vehicles and others drowning upon trying to escape or rescue others (Ashley and Ashley 2008; Diakakis and Deligiannakis 2013; FitzGerald et al. 2010; Jonkman and Vrijling 2008; Jonkman and Kelman 2005; Peden et al. 2017; Terti et al. 2017). Previous studies have found increased vehicle-related flood fatalities during evening or nighttime, when poor visibility combines with higher traffic density (Terti et al. 2015, 2017), and rapid, ''short fuse'' events (Diakakis and Deligiannakis 2013; Sharif et al. 2012; Špitalar et al. 2014; Vinet et al. 2016), especially in ephemeral low-water crossings (Diakakis and Deligiannakis 2013; Gissing et al. 2017; Sharif et al. 2012). Gissing et al. (2017) found that flood deaths in Australia were linked to road characteristics such as the lack of guardrails, poor lighting, a bend in the road, and a dipping road grade. Furthermore, not all vehicles are submerged because of intentional entry; many vehicle-related drownings occur when vehicles lose control and enter road-adjacent water, often a result of hydroplaning, rolling over, ramping over guardrails, or even attempting to turn around to avoid floods on roads too narrow or choked with traffic (Gissing et al. 2017; NOAA 2019; Stjernbrandt et al. 2008).

Certain demographic characteristics have also been linked to vehicle-related flood mortalities. Most studies explain the high proportion of male victims (60%–80% across several studies) as related to risk-taking behavior among males (Ashley and Ashley 2008; Coates 1999; Diakakis 2016; Diakakis and Deligiannakis 2013, 2015; Franklin et al. 2014; Hamilton et al. 2018b; Kellar and Schmidlin 2012; Maples and Tiefenbacher 2009; Pearson and Hamilton 2014; Peden et al. 2016, 2017; Salvati et al. 2018; Sharif et al. 2012; Terti et al. 2017). A few acknowledge that some occupations, including emergency responders, and leisure activities expose males to flood risks more often than females (Coates 1999; FitzGerald et al. 2010; Jonkman and Vrijling 2008; Jonkman and Kelman 2005; Paul et al. 2018; Pereira et al. 2017; Salvati et al. 2018), but it should be noted that in some study areas, including the United States and Australia, any given driver on the road is more likely to be male and thus they are more likely to be exposed to floods while driving (Coates 1999; FitzGerald et al. 2010; Paul et al. 2018; Sisak 2015).

Age is difficult to compare because studies use different age ranges, but several studies have found that children and the elderly are at greater risk given their proportion of the population (Ashley and Ashley 2008; Coates 1999; Diakakis and Deligiannakis 2013; FitzGerald et al. 2010; Paul et al. 2018; Salvati et al. 2018; Vinet et al. 2016), perhaps related to inability to maneuver in water (Yale et al. 2003). In other cases, young adults appear to have greater risk (Drobot et al. 2007; Maples and Tiefenbacher 2009; Salvati et al. 2018). These studies do not take actual exposure to floods into account (i.e., the proportion of an age group likely to be on the road at a given time), which, like gender, will relate to activity travel behaviors (commuting, errands, etc.) of each group (Kim et al. 1998).

Other studies analyze flood risk perception and self-reported behavior in hypothetical or past events (Creutin et al. 2009, 2013; Drobot et al. 2007; Franklin et al. 2014; Hamilton et al. 2016a, 2018b; Lutoff et al. 2016; Ruin et al. 2008, 2014) or observe behavior in flooded areas (Gissing et al. 2016). For reviews of studies examining intentional entry into floodwaters, see Ahmed et al. (2018) and Becker et al. (2015). Frameworks such as the theory of planned behavior (Ahmed et al. 2018; Ajzen 1985, 1991; Hamilton et al. 2016b, 2018b; Pearson and Hamilton 2014) and protection motivation theory (Ahmed et al. 2018; Franklin et al. 2014; Rogers 1975) have been used to examine psychological factors that influence motorist behavior in flooded streets.

Such studies have shown that behavior is linked to whether the individual recognizes and personalizes the danger (Drobot et al. 2007; Hamilton et al. 2016b, 2018b) or believes that the behavior would be approved by others (Hamilton et al. 2016b, 2018b). Previous experience also influences willingness to enter floodwaters; past positive experience such as a successful crossing increases willingness (Hamilton et al. 2016a; Pearson and Hamilton 2014) and past negative experience such as a flood-related loss or unsuccessful crossing decreases willingness (Drobot et al. 2007; Hamilton et al. 2018b). Familiarity with the road is assumed to cause both risk-taking (Diakakis and Deligiannakis 2015; Maples and Tiefenbacher 2009) and risk-avoidance behavior (Hamilton et al. 2018b; Ruin et al. 2007). Other factors include lack of acceptable alternatives, urgency of the trip, perceived environmental conditions, self-efficacy, and vehicle efficacy (Drobot et al. 2007; Hamilton et al. 2016a).

The present study builds upon this previous literature by adding the cultural theory framework to explain the behavior of driving into flooded roadways despite increasing efforts to improve warnings and flood awareness programs such as ''Turn Around, Don't Drown'' [National Weather Service (NWS)]. The cultural theory framework promotes viewing risk perception and response through the lens of culture, which mediates how people receive, interpret, and act upon hazard information (Douglas 1992; Douglas and Wildavsky 1982). Culture refers to a way of life learned from and shared by a social unit, including—but not limited to—attitudes, beliefs, values, and habits. Values and social norms shape an individual's worldview and therefore affect how the individual will understand threats and determine appropriate methods of threat avoidance or amelioration (Douglas 1992; Douglas and Wildavsky 1982). The resulting behaviors either maintain or reshape those norms, values, and practices (Fiske et al. 1998; Kitayama and Markus 1995; Markus et al. 1997; Shweder 1995). In sum, the way people think about their environment and risk is learned through socialization.

Douglas's cultural theory framework suggests that the way people perceive and respond to hazards depends on the presumed role of individuals in society, especially the degree of individuals' freedom to fill various social roles (social autonomy) and the degree of integration within social networks (social incorporation) (Douglas 1992; Douglas and Wildavsky 1982). This model has been criticized for being rigid and simplistic with only four culture categories (Lupton 1999; Verweij et al. 2011), but it has nevertheless been adapted to consider the four categories as a spectrum along which an individual or group's position may change over time (Offermans et al. 2009). While no social unit or individual is exclusively one cultural type or another, the norms and values associated with these categories are present and affect risk perception, hazard mitigation strategies, and response behavior. Of the cultural factors that Douglas emphasizes, this study focuses on how trust, self-efficacy, and social incorporation influence risk perception and behavior.[1]

As an adaptation to a complex environment, people place trust in those whom they believe to have both the knowledge and willingness to share accurate information about particular risks (Earle and Cvetkovich 1995; Lang and Hallman 2005; Savadori et al. 2004; Siegrist and Cvetkovich 2000; Slovic 1999, 2000). In the case of flash floods, the public must place trust in the agency or individual delivering the warning or information and the message itself. Some research has shown that individuals may lack trust in an agency because they perceive the agency to be too far removed from both daily situations and extreme events (Handmer 2001; Parker and Handmer 1998; Savadori et al. 2004). As a result, individuals may seek hazard information from the sources they do trust, such as friends and family (Handmer 2001; Mileti 1995; Parker and Handmer 1998).

A second factor, self-efficacy, describes whether individuals or groups determine that a risk may actually be reduced as well as whether they are capable of taking the proper precautions or reactions during a hazard event (Ashley and Ashley 2008; Hamilton et al. 2016a, 2018b; Wisner et al. 2004). Self-efficacy primarily refers to an individual's apparent locus of control (Bandura 1997; Scholz et al. 2002). An individual with an internal locus of control feels in charge of his or her actions and destiny. They may react to warnings by taking measures to secure life and property because they believe taking action will improve outcomes, or conversely, they may feel invincible and take no precautionary or reactionary measures. Individuals with an external locus of control tend to feel helpless in hazard situations and depend on others for protection. Individuals with low self-efficacy may also assume that they cannot alter their destiny by taking precautionary or reactionary measures or may have little faith in their decision-making capability (Douglas 1992; Inelmen et al. 2004). Thus, self-efficacy produces a variety of possible responses and requires careful consideration. Previous work examining motorist behavior with respect to floods associated high self-efficacy with flood avoidance behavior when framed as

[1] Time perspective and social autonomy were two additional factors that were included in the analysis, but the results are not reported here.

having the knowledge and ability to assess and avoid risk (Hamilton et al. 2016a, 2018a, 2018b; Pearson and Hamilton 2014). Drobot et al. (2007) also found that low self-efficacy linked with past trauma was associated with crossing behavior. However, when the efficacy concept is shifted to the vehicle, high vehicle efficacy (e.g., four-wheel drive or high clearance) is linked to decisions to enter floodwater (Hamilton et al. 2016a, 2018b).

The third factor, social incorporation, is defined by Douglas (1992) as the extent of an individual's social network and the degree of connection between its members. Douglas uses the term to differentiate between individualist societies and collectivist societies, the latter of which value collaborative decision-making and would be more concerned with social approval. Many studies have shown that people seek confirmation of the severity of a hazard and the need to prepare or respond appropriately from a variety of sources before they will take action (Brilly and Polic 2005; Creutin et al. 2013; Mileti 1995; Ruin et al. 2014), including official sources as well as informal sources such as friends and family. Similarly, collective-oriented people may consider their responsibility to others and how others will perceive their decisions regarding risky behavior, including driving into flooded roadways (Hamilton et al. 2018b; Pearson and Hamilton 2014). For this reason, Parker and Handmer (1998) and Handmer (2001) recommend that risk managers attempt to understand how people exchange information within their social networks.

The social amplification of risk framework (SARF) provides a theoretical model for how risk perception is amplified or attenuated as people consult with their social networks and share information about hazards (Kasperson and Kasperson 2005; Kasperson 1992; Ley García et al. 2019; Masuda and Garvin 2006). Individuals will spread information that conforms to prior perceptions of reality, which are influenced by culture. Individuals who have high risk perception will amplify risk by sharing warnings with others, potentially raising overall risk perception among the group. Those who have low risk perception will attenuate risk by circulating contrary information or failing to propagate any information at all, thus lowering overall risk perception (Kasperson 1992; Masuda and Garvin 2006). SARF implies that exchanging information with others enables individuals to establish similar conceptualizations of the nature of hazards, including the best and worst ways to prepare for and respond to events (Morris-Oswald and Sinclair 2005). However, the relationship between risk perception and attenuation or amplification of risk is not always straightforward, and those who perceive lower risk may do so precisely because they are better informed and prepared (Ley García et al. 2019).

The cultural theory framework demonstrates that many complicating factors affect the success of risk communication through educational campaigns. Individuals must weigh competing risks, access to information that could aid decision-making is not always available, and circumstances may prevent protective action (Beck et al. 1994; Montz et al. 2017; Wisner et al. 2004). Additionally, cultural norms partially determine what information is trustworthy, how people receive information, and which actions are deemed reasonable and acceptable under given circumstances. The present study considers these issues to examine how people interpret information from official sources, how that information is mediated by social interactions and observations, and how information from different sources is factored into decision-making when flooded streets are encountered. The following hypotheses are examined: with respect to cultural factors, those who report past crossing behavior will demonstrate 1) lower trust in warning messages and their sources, 2) higher self-efficacy, and 3) fewer social interactions regarding floods. For situational factors, 4) deterrents will have lower influence and 5) incentives will have higher influence on the decisions of those who report crossing behavior. Last, 6) larger vehicles will be associated with higher rates of crossing behavior.

3. Case study: Flash floods in Tucson

According to the 2010 census, approximately 575 000 residents live in the city of Tucson and the immediate vicinity, including towns such as South Tucson and Oro Valley (U.S. Census Bureau 2017). Although located in a semiarid region, intense convective thunderstorms are common during the North American monsoon season (mainly July and August). Hundreds of streets and intersections may flood in response to these intense rains due to a combination of low-water crossings that traverse normally dry washes and streets that have been designed to convey stormwater. As a result, flood events need not be extreme to disrupt traffic and constrain mobility. Motorists are exposed to these highly localized floods any time it rains, which occurs on average 50 times per year and 8–10 times per month during July and August as based on data collected from rain gauges around the city (NRCC 2019).

A municipal program known as "Operation Splash" attempts to deter motorists from driving into flooded roadways using permanent signs, seasonal A-frame signs, and road barriers (see Fig. 1). The locations of flood-prone areas are frequently mentioned in outreach

FIG. 1. Types of flood signs: (a) dip sign at Sarnoff Road and 24th Street and (b) dip sign and A-frame on Highland Avenue at the Arroyo Chico Wash while flooded to a depth of ~4 ft (1.2 m). This particular dip crossing was recently eliminated by the installation of a bridge and culvert. Photograph credits: A. Coles.

programs and through the local television and print media (Tucson Department of Transportation 2015) and are shown here in Fig. 2. An Arizona state law (ARS 28-910), popularly known as "the stupid motorist law," requires individuals who drive around barriers to pay for costs incurred during swift-water rescue (Arizona State Legislature 2006). Despite the publicity surrounding the law and the programs designed to communicate the dangers of driving through flooded roadways, losses to life and property continue to occur. According to the Storm Events Database (NOAA 2019), six individuals have perished in vehicle-related flood incidents in the immediate vicinity of Tucson since 1996. Over this period, there are over 150 reports mentioning stranded vehicles or swift water rescues; the total number of incidents is much higher because database entries often report multiple strandings or rescues as a single event. For example, the entry describing an extreme flash-flood event that occurred on 31 July 2006 estimates that 100 vehicles were flooded.

4. Methods

The data for this study were collected during 2007 and reanalyzed in 2018. Data collected include two focus group interviews with flood risk managers in Tucson and a mail-in survey questionnaire distributed to randomly selected Tucson households. Although the original data were collected over a decade ago, the flood context and outreach programs have changed little. One significant change is the more widespread adoption of mobile telephones, particularly "smart phones," as a means of communication and seeking further information. The implications of this shift for future research and flood risk communication are described in the discussion section.

a. *Focus group interviews design and analysis*

To ensure the relevance and utility of information gathered in this study, flood risk managers from the agencies responsible for flood management and the dissemination of flood information in Tucson participated in two focus group interviews. Participants were identified and invited based on Internet searches of agency personnel or by referral. The five participants included members of the Tucson National Weather Service Weather Forecast Office, the Pima County Regional Flood Control District, and the Tucson Department of Transportation.

At the first meeting in May 2007, participants discussed their experiences in flood risk management and their suggestions for the structure and content of the

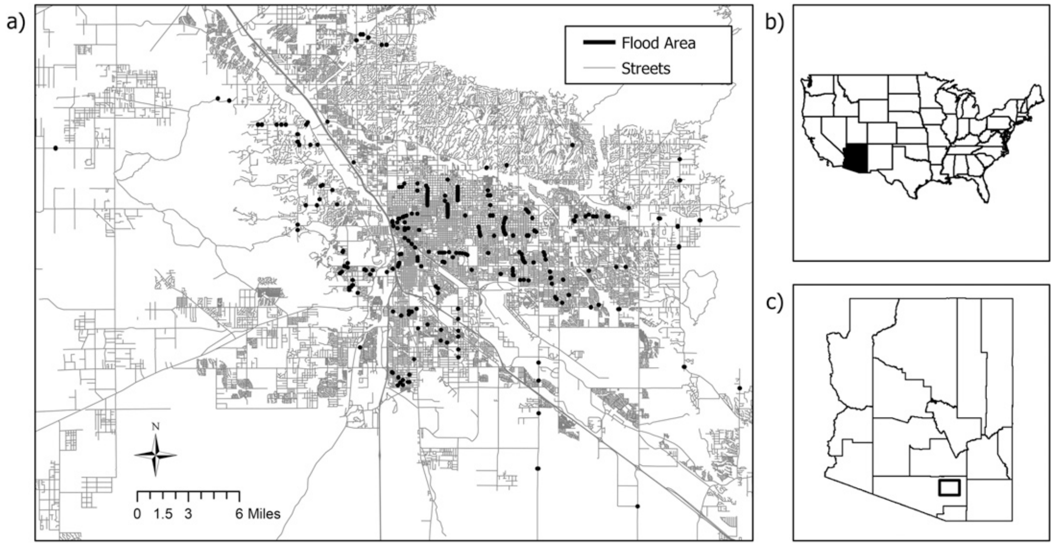

FIG. 2. Map of Tucson streets and flood areas: location of (a) the study area (b) within Arizona and (c) Pima County; the map in (a) shows the locations of streets that flood when it rains, each of which is marked by one or more warning signs. Locations were obtained from the data portals of the city and county governments (City of Tucson 2018; Pima Association of Governments 2018).

survey instrument. Topics included locations of flood-prone areas, possible factors that influence an individual's decision to cross or not to cross a flooded roadway, and the effects of stigma and the so-called stupid-motorist law. Suggestions provided by focus group participants were used in the survey instrument, which was disseminated in the autumn of 2007.

The same participants attended a second focus group interview after initial data analysis, during May 2008. The results of the survey were presented to flood risk managers, who responded to the results and discussed the potential applications for flood management in Tucson. The themes described in both focus group interviews were hand coded and analyzed using content analysis.

b. Survey design and sampling method

Survey questionnaires were mailed to 1000 Tucson residents, selected at random from the areawide residence directory, in both English and Spanish. Surveys were mailed in September, at the end of the monsoon season, so recipients would have recent events to recall. Questions elicited information regarding the cultural factors outlined above by asking participants whether they agreed or disagreed with a series of statements on a five-point Likert scale. Other questions provided explicit situational factors related to flash floods and asked participants to indicate to what degree each factor would influence them to cross or not to cross a flooded roadway on a four-point Likert scale.

To minimize the potential bias from a desire to report approved or ''correct'' behaviors (in this case, not entering floodwaters), this section was introduced with the following statements: ''There are many reasons why a person might decide to drive through a flooded roadway. How much influence would the following factors have on your decision to drive through a flooded roadway?'' Flooded roadway was defined in the survey as one in which ''you cannot see the road surface under the water, making the depth difficult to estimate and possibly hiding underwater debris or street erosion.''

Participants were asked to provide their typical responses (what do you normally do) or hypothetical responses (what might you do) to encountering a flooded street crossing. The survey included space for short answer responses that allowed the participants to elaborate or explain their selections. This survey design allowed for quantitative analyses without sacrificing the opportunity for participants to provide deep, rich information not predetermined by the investigators (McGuirk and O'Neill 2005). The free response answers also explain some contradictory or surprising answers provided by the participants.

c. Survey sample demographics

Of the 173 surveys returned, five individuals refused to indicate whether they had crossed flooded roadways; hence they are excluded from the statistical analysis. The remaining 168 survey respondents did not reflect a sample representative of Tucson demographics according to 2000 and 2010 census data in the categories of ethnicity, education, and age (U.S. Census Bureau 2001, 2017). In comparison with all Tucson residents, respondents were disproportionately White, college educated, and older (see Table 1). Approximately 52% of survey respondents identified as female and 47% identified as male. The mean and median age of the sample is 58 years. The survey design did not adequately capture the age of crossing for some participants, who may have done so decades ago or months ago. However, results show that individuals of all ages are driving through flooded roadways.

Self-selecting sampling bias likely explains higher-than-expected numbers of respondents with higher ages and education levels. Although the nature of the sample raises concerns about the generalizability of this study, the results provide insight into common experiences and complex reasoning behind seemingly contradictory behaviors. Other social groups may weigh factors differently, but the challenges that this sample faces when deciding whether to drive through flooded roadways are likely experienced by others and should be considered in flood management strategies and other risk perception research. Further studies that target the underrepresented groups may be critical for the identification of additional challenges.

d. Survey analysis

The objective of this study was to determine which factors influence an individual's decision to drive through a flooded roadway, so each factor was analyzed with respect to the question "Have you ever driven through a flooded roadway?" Respondents answered yes or no to this question and then provided details about the situational context and their thought processes regarding the decision in a free-response format. A narrative analysis was performed on the free response answers, which were used to triangulate the responses individuals provided to other questions. For simplicity, those who responded "yes" have been labeled "crossers" and those who responded "no" have been labeled "noncrossers." Of the 168 respondents included in this analysis, 39% are noncrossers and 61% are crossers.

Pearson chi-square analysis was used to determine whether crossing behavior was linked to vehicle size, since the participants were able to select more than one method of transportation and the response for each category is a binary yes or no. For the Likert scale responses, including the cultural and situational factors, one-way ANOVA was used to compare means and test for statistically significant differences (level $p \leq 0.05$) between crossers and noncrossers, as well as among subsets of those groups based on gender, education, and household income. All the results reported here meet the standard assumptions for Pearson chi-square and ANOVA analysis (e.g., Bartlett's test); those that did not have been excluded.

The open-ended survey questions were hand coded and subjected to content analysis in order to triangulate the responses in the quantitative analysis. Participants were asked to explain their typical or hypothetical behavior in instances where they would ultimately cross a flooded roadway or choose not to cross a flooded roadway, and in this manner, they provided further explanation and justification for their actions. Content analysis was also used to determine how participants exchange information within their social groups, elaborating this specific dimension of social incorporation combined with SARF.

TABLE 1. Comparison of survey demographics with 2000 and 2010 U.S. Census data for Tucson.

	Survey sample	2000 Census	2010 Census
Ethnicity			
White	85	70.2	69.7
Hispanic or Latino	4.4	35.7	41.6
Black or African American	0.6	4.3	5.0
Asian	0.6	2.5	2.9
American Indian or Alaskan Native	0.6	2.3	2.7
Native Hawaiian or other Pacific Islander	0	0.2	0.2
Other	3.7	—	—
Education			
Bachelor's degree	63	23	25

5. Results

The results reported here emphasize participants' perception and usage of official flood warning messages in conjunction with other sources of information, including environmental cues and social interactions. The first section examines situational factors that deter and incentivize entering floodwaters. The second section examines cultural factors including trust, self-efficacy, and social incorporation.

a. Situational factors: Deterrents and incentives

The survey asked respondents to indicate to what degree various factors influence their decision when confronted with a flooded roadway. Possible responses include *no influence* (0), *slight influence* (1), *moderate influence* (2), and *strong influence* (3). For this analysis, a higher mean indicates a stronger influence on the decision. A few high-publicity incidents had led flood risk managers to predict that rescue fines and potential embarrassment would be strong deterrents, but, with few exceptions, respondents indicated that those factors were the least influential.

Factors that deter motorists from driving through flooded roadways are listed in Fig. 3. For most deterrents, the mean influence is higher for noncrossers than for crossers, but the difference is only statistically significant for three factors (against the law, family in the car, friends in the car). Surprisingly, three of the consequence-related deterrents (danger, damage to vehicle, fees for rescue) show higher means for crossers than noncrossers, though the difference is not statistically significant. Hypothesis 4 is partially supported by these results. The risk of injury or death is the factor that has the most influence for all respondents, including both crossers and noncrossers (mean = 2.90). Approximately 90% of all respondents indicated that danger is a *strong influence* on their decision not to cross. Potential vehicular damage was also high among the reasons for not crossing (mean = 2.66), rated as a *strong influence* for 77% of respondents. In other words, the possibility of incurring negative consequences is a compelling deterrent for most people in this study, including those who have crossed a flooded roadway. In fact, 64% of respondents said that there had been at least one situation in which they considered crossing a flooded roadway and decided against it. Of those individuals, 72% said that they had at some point crossed a flooded roadway. Even if you remove the three individuals who ''learned their lesson'' from the previous experience of crossing and say they will never do it again, many respondents make the decision on a case-by-case basis after carefully weighing their options and the situation. Some explained their risk threshold in the free response. For example, one respondent wrote: ''If road is flooded and level and other cars going through, generally will go. If a dip or water actually running will not go through.'' Thus, circumstances influence crossing behavior even among those who ''know better.''

Incentives to cross are listed in Fig. 4. The overall degree of influence is much lower on average for the incentives to cross because many participants selected ''no influence'' (0); this is particularly true for noncrossers. The successful prior crossing of another vehicle has the strongest influence on motorists' decisions (mean = 1.44), and having family on the other side is the second strongest influence (mean = 1.00). The difference in mean influence between crossers and noncrossers is statistically significant in several categories, supporting hypothesis 5 (see Fig. 4).

The relative influence of specific circumstances was the key difference found between males and females (see Figs. 5 and 6). When asked to what degree situational factors influence their decision to cross, the successful crossing of another vehicle and family on the other side were ranked as the highest and second highest influence for both genders. However, not knowing an alternate route ranked as third highest influence for females (mean = 1.01) but only the fifth highest for males (mean = 0.70). Conversely, knowing an alternate route is a stronger deterrent for females (mean = 2.65), for whom that factor ranked as the fourth strongest influence. For males, knowing an alternate route ranked as the seventh strongest influence (mean = 2.31). Awareness of an alternate route is a critical factor in a driver's decision and is particularly important for female drivers.

b. *Cultural factors*

1) Trust in official warnings

Each of the flood risk managers indicated that one of their major concerns was building the public's level of trust in their information and warnings. Whether the public is more skeptical about the nature of the hazard, the message, or the messenger, the goals of the focus group participants include ''trying to figure out how we can have people heed the warnings that we put out.'' Respondents were asked whether they trust various sources of information to provide accurate information about flash floods on a five-point Likert scale with the options *do not trust at all* (1), *mostly do not trust* (2), *neutral* (3), *mostly trust* (4), and *completely trust* (5). The mean values for all respondents were calculated for each source, so a high mean indicates high levels of trust and a low mean indicates low levels of trust. A sixth category, *not applicable/do not use*, was also available as a response but not used to calculate mean. Sources included various media outlets, safety officials such as police and firefighters, official warnings, friends and family, and environmental cues (see Table 2). Official warning messages refer to those provided by the aforementioned agencies involved in flood hazard management: the flash-flood warnings issued by the NWS, the flood warning signs and road barricades located at low-water crossings, and general flood information distributed via mailers, websites, and local media (see Fig. 7).

Approximately 66% of respondents indicated that they mostly or completely trust general information from the NWS (mean = 4.20). For NWS flash-flood warnings, 73% of respondents indicated trust (mean = 4.33). NWS warnings generally describe large areas

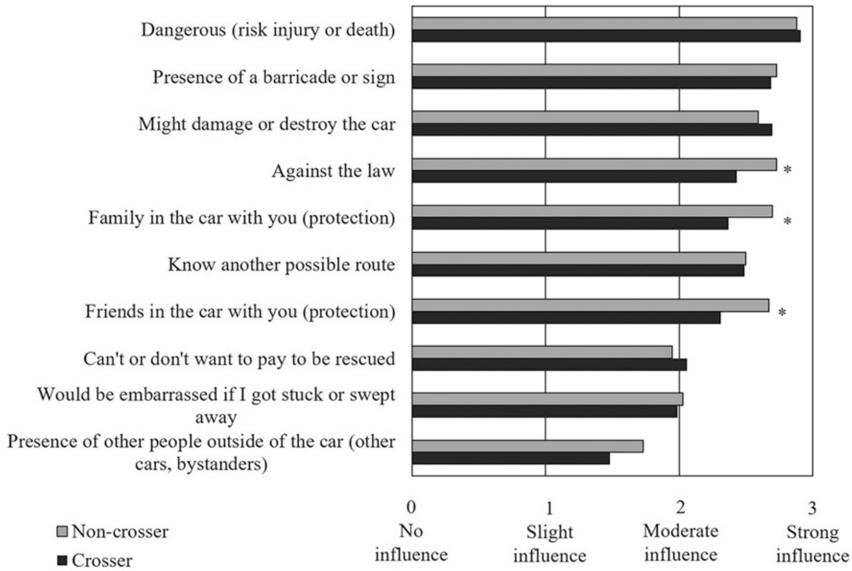

FIG. 3. Deterrent factors to entering floodwaters by crossing behavior, listed in order of overall mean influence. An asterisk denotes $p \leq 0.05$ in the ANOVA comparing crossers and noncrossers.

(e.g., ''eastern Pima County''), rather than specific locations. An extremely dense network of spotters and gauges would be required to verify and report flooding associated with the localized convective storms typical of the monsoon. The signs and barricades are therefore critical for providing more detailed information.

Each of the flood risk managers had expressed concern that individuals do not trust the signs and barricades. However, many noncrossers and crossers indicated high levels of trust in both. Overall, 77% of respondents indicated trust in ''dip'' signs (mean = 4.22) and 83% in barricades (mean = 4.39). The proportion of the sample indicating trust versus distrust was approximately equal among crossers and noncrossers, though the mean for noncrossers is statistically significantly higher for both the signs ($p = 0.042$) and barricades

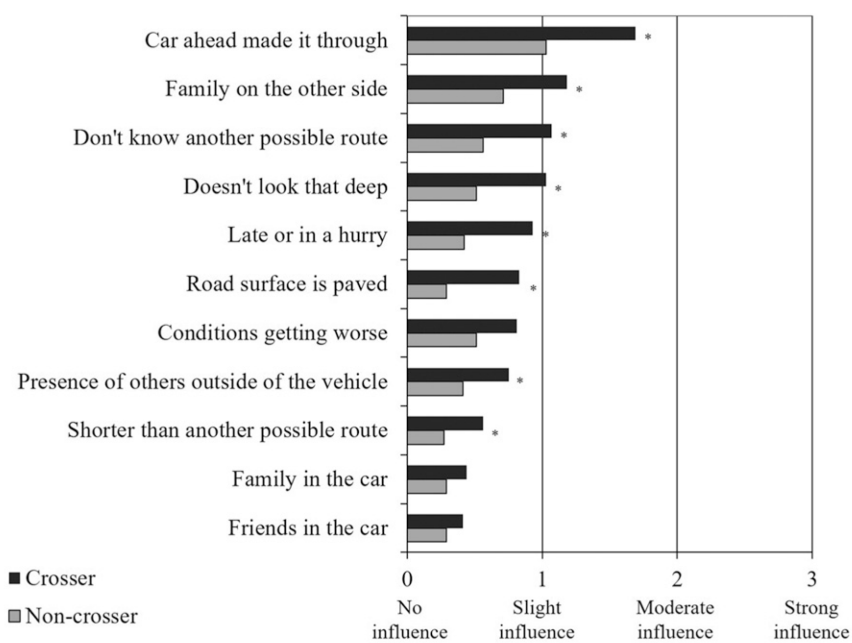

FIG. 4. Incentives to enter floodwaters by crossing behavior, listed in order of overall mean influence. An asterisk denotes $p \leq 0.05$ in the ANOVA comparing crossers and noncrossers.

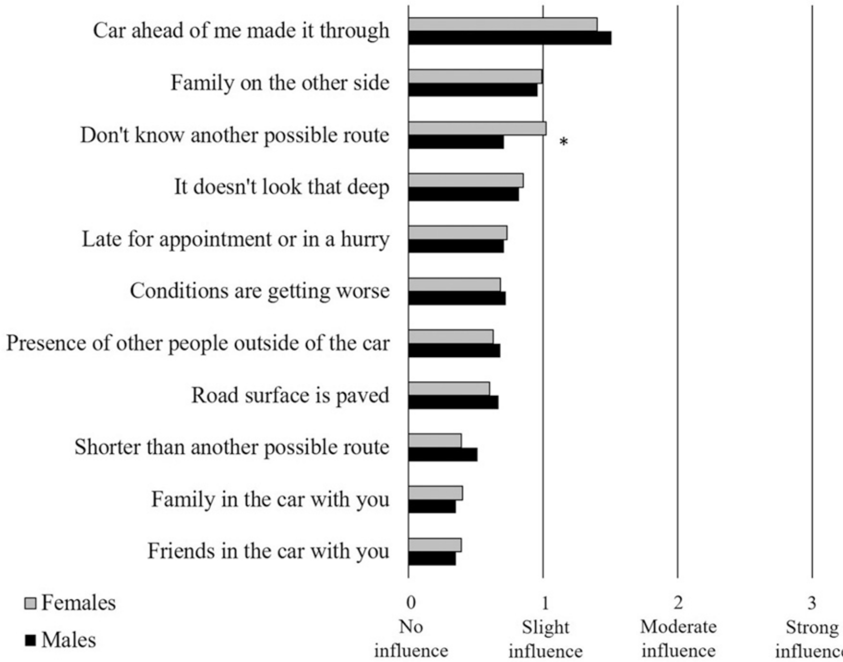

FIG. 5. Incentives to enter floodwaters by gender, listed in order of overall mean influence. An asterisk denotes $p \leq 0.05$ in the ANOVA comparing males and females.

($p = 0.017$), supporting hypothesis 1. Many respondents reported in their free responses that the lack of a barricade or sign influenced their decision to cross and that they would never cross if a barricade were present; 90% of participants indicated that the presence of a sign or barricade would *strongly influence* their decision not to cross a flooded roadway, with no statistically significant difference between crossers and noncrossers. Their responses also support the suggestion brought up by one focus group participant that the signs and barricades produce a false sense of security in unmarked areas, leading individuals to believe that the *lack* of a sign indicates the lack of flood danger.

Proper signage does not guarantee a clear signal of danger, however. One flood risk manager suggested that the daily presence of the signs causes them to become ‘‘background noise.’’ The ‘‘dip’’ signs are permanent, and the A-frame signs and barricades are erected when rains are expected to cause flooding or after flooding has begun, and may remain up for some time after flooding has ceased. Nearly 90% of all respondents agreed that signs or barricades indicate the *likelihood* of flash floods occurring in that particular section of the roadway (mean = 4.32), but only 43% agreed that the signs or barricades indicate the *degree* of danger (mean = 3.18). These results suggest that the respondents note the possibility of danger at low-water crossings marked with signs and barricades, but do not assume that their presence automatically signifies that water on the roadway is impassable. Indeed, one respondent noted in the free response that the signs and barricades remain even when the water is ‘‘a trickle, not flooded’’ and that they relied more on environmental cues. Eighteen respondents described attempts to assess the depth or velocity of water using known benchmarks or other vehicles for comparison. Notably, no respondents reported that they did *not* trust environmental cues, but 16 individuals explained that in the past they had decided not to cross because the environmental cues were not clear. For example, an individual stated that in one instance they ‘‘didn't know how deep it was and decided not to take the risk.’’

An important set of environmental cues include whether other vehicles appear to be safely navigating the water. Previous studies have found that many drivers followed another's lead, whether crossing the floodwaters or turning around (Gissing et al. 2016; Pearson and Hamilton 2014). Respondents in the present study indicated that the factor that most strongly influences their decision to cross a flooded roadway is the successful prior crossing of another vehicle. For 76% of respondents, another vehicle's successful crossing has at least a slight influence on their decision to cross. Twenty-one respondents noted in the free-response section that they have waited to see if other vehicles successfully crossed before deciding and will usually follow especially if they perceive their own vehicle to be larger, have a higher

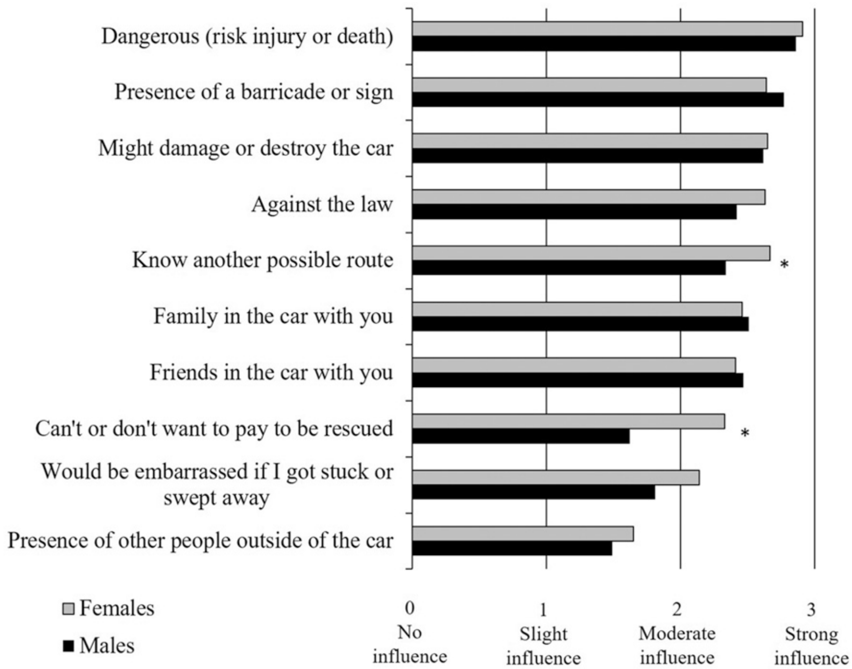

FIG. 6. Deterrent factors to entering floodwaters by gender, listed in order of overall mean influence. An asterisk denotes $p \leq 0.05$ in the ANOVA comparing males and females.

clearance, or be heavier than the vehicles that successfully crossed. Four respondents also reported using the vehicles in front of them to determine how deep and swift the water is moving across the roadway. They also use this strategy to assess whether an unfamiliar road is relatively flat or has a dip, since it can be difficult to tell in the absence of a depth meter or curbs (see Fig. 1b). However, three respondents mentioned an instance in which they found themselves alone on the road or did not wait for other vehicles to cross successfully because they felt confident that their vehicle was large or safe enough. One respondent said that "although some cars refused to drive through I thought my truck could make it." Other respondents indicated that having four-wheel drive factors into their decision to cross as well.

The results also support the flood risk managers' prediction that people feel more confident about driving through flooded roadways in larger vehicles. Respondents were asked about their primary mode of transportation within the city and were allowed to select multiple answers. Choices included car, sport utility vehicle (SUV), truck, motorcycle/scooter, bus, bicycle, walking, and

TABLE 2. Trust in sources of information by crossing behavior: mean trust for all responses combined and separated into crossers and noncrossers. Higher means indicate higher levels of trust. An asterisk denotes significance level $p \leq 0.05$ in the ANOVA comparing crossers and noncrossers.

Source	Total mean	Noncrosser mean	Crosser mean	p
Local television news channel	4.24	4.40	4.15	0.065
Local radio station	4.00	4.11	3.95	0.422
The Weather Channel	3.83	4.00	3.71	0.142
NWS general information	4.20	4.22	4.20	0.878
NWS flash-flood warnings	4.33	4.38	4.29	0.539
Environmental cues	4.59	4.56	4.60	0.686
NOAA Weather Radio	4.28	4.32	4.26	0.856
"Flood area" barricades	4.39	4.61	4.24	0.017*
"Dip" signs	4.22	4.41	4.09	0.042*
Neighbors, friends, and family	3.81	3.97	3.72	0.114
Police	4.46	4.66	4.34	0.021*
Firefighters	4.61	4.75	4.52	0.046*
Emergency responders	4.53	4.68	4.44	0.061

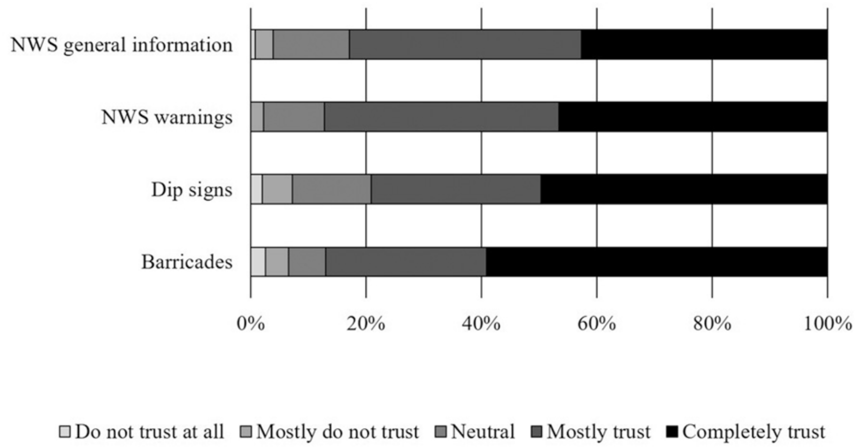

FIG. 7. Percentage of respondents who do or do not trust the official sources of flood information to provide accurate information. Differences between crossers and noncrossers are not shown because proportions are approximately equal.

other. With the exception of motorcycle/scooter and bus, a higher percentage within each vehicle type identified as crossers than as noncrossers. However, there are significant differences when crossing behavior is broken down by whether the individual drives a large vehicle, such as a truck or SUV (see Fig. 8).

A Pearson χ^2 analysis shows that that crossing behavior differs among drivers of small and large vehicles. The proportion of crossers is 51% for small vehicles and 77% for large vehicles ($p = 0.001$), thus supporting hypothesis 6. Although five respondents indicated in the free response that vehicle size does not matter in more severe circumstances, there appears to be a widespread belief among participants that larger vehicles are a safer means of crossing flooded roadways.

2) Self-efficacy and gender

Self-efficacy was measured using questions from the General Self-Efficacy Scale (GSES; Scholz et al. 2002), Drobot et al.'s (2007) study of driving behavior in floods, and original questions specific to this project. Answers were coded along a five-point scale with 1 representing low self-efficacy and 5 representing high self-efficacy. Mean self-efficacy scores were calculated for each individual question as well as a combined scale averaging the GSES questions. Mean self-efficacy was higher for noncrossers (4.02) than for crossers (3.79), though not statistically significant ($p = 0.104$). Most of the variation is among males. For females, there was no statistically significant difference in self-efficacy among crossers (mean = 3.70) and noncrossers (mean = 3.79). Among males, however, noncrossers demonstrate higher levels of self-efficacy (mean = 4.32) than crossers (mean = 3.86; $p = 0.053$). Thus, at least for males, an internal locus of control is associated with noncrossing behavior rather than crossing behavior, which does not support hypothesis 2. Additionally, for the question "I consider myself a good judge of whether flood waters are dangerous," males had a slightly higher mean (3.89) than females (3.57; $p = 0.042$). Despite this variation, the present study shows no statistically significant difference in reported crossing behavior among women and men, who admit to driving into floodwaters at approximately equal rates.

3) Social incorporation and SARF: talking about floods

The survey asked about the social networks within which respondents send and receive information about

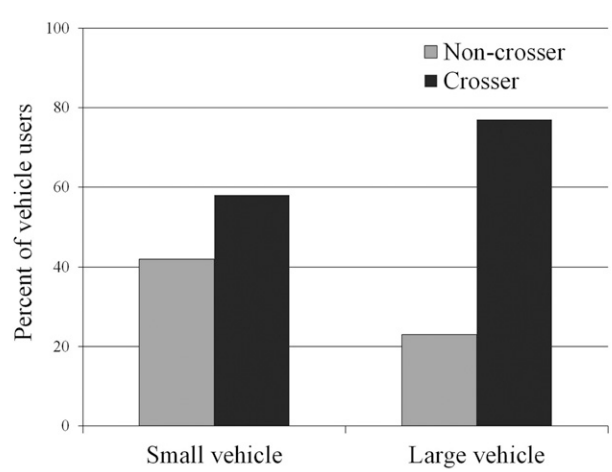

FIG. 8. Vehicle type: proportion of people who have entered floodwaters (crossers) and those who have not entered floodwaters (noncrossers) among drivers of small ($N = 127$) and large ($N = 72$) vehicles. The Pearson χ^2 $p = 0.001$.

flash floods. The first question asked to whom they would go to for advice or help during a flash flood, providing examples such as ‘‘brother’’ or ‘‘neighbor.’’ Seventy-nine percent of all respondents listed at least one person that they would go to for advice or help during a flash flood, with similar proportions for crossers and noncrossers, contrary to hypothesis 3.[2] Family, friends, and neighbors were the most common responses, perhaps biased because of the examples suggested, but coworkers, police, and firefighters were also frequently mentioned. Other responses were more specific to the situation, such as ‘‘someone who might be familiar with route I am taking,’’ and ‘‘If I got caught in one—dad, brother. Where it is and how to avoid—dad, brother, friends.’’ The number of respondents seeking advice from friends, family, and neighbors is surprising given that average level of trust in the flood information from this category was a relatively neutral 3.81, the lowest average among all listed sources. From these explanations, it appears that friends, family, and neighbors are viewed as useful sources for route information, including how to avoid floods.

The second question asked respondents with whom they discuss flood-related information during nonflood periods. Again, the relative percentages of crossers and noncrossers were approximately equal, with about 51% of all respondents listing at least one person with whom they discuss flood-related information when it is not currently flooding—primarily family, friends, neighbors, and coworkers. One respondent described the information as ‘‘not relevant’’ between events; another does not discuss flood-related information when it is not flooding, ‘‘unless it is monsoon season.’’ While the conversations are less frequent than during flood events, the fact that half of respondents discuss floods between events demonstrates the salience of flooding in the area even when roads are dry.

Notably, many respondents indicated that they actively exchange information about flood-prone areas and alternate routes with others either by volunteering the information or asking for it. As an example of the type of information that propagates through social networks, four respondents mentioned in the free-response section that upon moving to Tucson they had been warned to stay out of the washes and underpasses by friends or colleagues. One respondent mentioned that they ‘‘tell newcomers to pull off the road and have a cup of coffee during heavy rains,’’ indicating that they relay the dangers of driving in the rain as well as the typically brief duration of the inconvenience. While some newcomers to Tucson were warned about the floods, others lamented that they had not been warned and were surprised to see so much water on the roads. One crosser described their experience:

> I had no idea (there was no sign) what was going on and when I realized the road was basically a river I drove way up high on the side to get out of it. I was new to Tucson and had no idea that streets were constructed to run water down the middle. What poor street construction!

Six others expressed frustration with the road design, since stormwater could be channeled through storm drains or flood-prevention infrastructure, but vehicles may only travel through the streets. The flood risk managers explained that this design moves stormwater most efficiently in terms of time and cost, especially since scouring flows can plug or destroy infrastructure with debris, but this explanation is not typically included in educational outreach.

6. Discussion

There are expansive education campaigns each year warning drivers of the dangers of flooded streets and washes, yet people continue to drive into floodwaters. Local flood risk managers had hoped this study would provide information that would help them adjust their warning messages such that people would believe them and afterward avoid the risk. However, regardless of reported crossing behavior, respondents overwhelmingly indicated that they already do trust the flood risk managers, believe their warning messages, and understand that driving through flooded roadways potentially leads to injury, death, and financial loss. Even if this sample is nonrepresentative, there are numerous individuals who understand the dangers of driving into flooded streets but still do it from time to time. Further examination reveals that for many drivers, how the warnings apply in particular situations remains unclear.

The degree of influence for several incentives and deterrents differs among crossers and noncrossers, with the unsurprising pattern that deterrents are a stronger influence for noncrossers in some categories (partially supporting hypothesis 4) and most incentives are a stronger influence for crossers (supporting hypothesis 5). Notably, crossers do weigh deterrents in their decisions, and many of them have reported that they decided not to enter floodwaters on other occasions, indicating that these factors are not fully disregarded or misunderstood. The rank importance of deterrents and incentives differ from those found in Hamilton et al. (2018b) in that

[2] One question asked with how many people the respondent shares flood information, but too few provided an answer to permit analysis.

participants of the present study ranked vehicle damage higher and concern for others' opinions of their actions lower, but participants in both studies indicated high levels of concern for danger to oneself and their passengers.

Participants also consider vehicle efficacy, as vehicle size and four-wheel drive were frequently mentioned in the free response and those who drive larger vehicles were much more likely to report having entered floodwaters. These results support hypothesis 6 and echo previous studies showing vehicle efficacy as a factor for motorist behavior during floods (Hamilton et al. 2016a, 2018b). These results are not surprising given that the National Weather Service website reinforces such vehicle efficacy beliefs, stating, ''It takes just 12 inches of rushing water to carry away most cars and just 2 feet of rushing water can carry away SUVs and trucks'' (NWS 2019). While the website acknowledges flow velocity and potential road washouts as additional factors and recommends against driving into floodwaters under any circumstances, this guidance potentially sends a mixed message.

The presence of signs and barricades ranked as a strong deterrent for both crossers and noncrossers, but noncrossers report higher levels of trust in these official messages, supporting hypothesis 1. The challenge for motorists is that the signs do not provide sufficient information. Although the presence of signs and barricades indicates the potential for danger in that section of the roadway, motorists cannot tell whether water is impassable at that moment. The signs are semipermanent, so they rely on other sources of information to determine whether it is safe to cross, including environmental cues and acquaintances more familiar with the area. Since conditions are not always obvious, motorists observe the outcomes of others' flood crossing attempts for additional information about flow depth and velocity. It is therefore not surprising that the successful prior crossing of another vehicle is the strongest incentive for entering floodwaters.

Motorists would therefore benefit from additional information about current conditions, such as flashing light indicators and depth meters, which already exist at some low-water crossings. Both have their limitations, however. Depth meters provide an ambiguous message because their reflection in water can make the depth appear deceptively shallow (Jing et al. 2017). They also do not provide any information about flow velocity or whether the road surface has been washed out, which add significant threat.

In addition to clearer information about current conditions, motorists encountering flooded streets need further instruction beyond ''Turn Around, Don't Drown.'' While previous works have suggested that high self-efficacy has the potential to cause both risk-taking and risk-averse behavior (Bandura 1997; Douglas 1992; Inelmen et al. 2004; Scholz et al. 2002), the authors and the flood risk managers had hypothesized that in the case of motorist behavior during floods, high self-efficacy would be associated with risk-taking behavior (hypothesis 2). However, there is no statistically significant difference between the self-efficacy levels of crossers and noncrossers except among males, and among males those with higher self-efficacy are less likely to have entered floodwaters. Previous studies have linked risk-averse behavior to high self-efficacy when motorists have more confidence in their ability to avoid floods, including knowing an alternate route (Hamilton et al. 2016a, 2018b; Pearson and Hamilton 2014). Raising this form of self-efficacy by communicating specific instructions for avoiding floods would therefore likely promote risk-averse behaviors, particularly if instructions such as alternate routes could be provided with mobile telephone ''apps'' that would be accessible to a motorist encountering floods in transit. For example, websites that provide real-time data about flood-related road closures, such as those in Fort Worth (City of Fort Worth 2019) and Austin (ATXfloods 2018), Texas, could be incorporated into navigation apps to generate safer alternate routes.

Since the official warning messages do not provide concrete suggestions for what to do if one encounters a flood, many residents are learning what to do from each other. In some cases, that information—or lack thereof—has proved extremely important to new arrivals unaccustomed to the nature of flooding in Tucson. Most respondents exchange flood-related information while it is flooding, but many also discuss it between events. Survey respondents seek and provide information about flood danger, flood locations, and alternate routes. In this respect there is no apparent difference between crossers and noncrossers, so these results do not support hypothesis 3.

Moreover, the fact that individuals discuss floods at all, especially between events, has important implications related to the SARF. The surveyed individuals tend to amplify the risk of driving into flooded roadways by warning newcomers and loved ones about the danger. These results suggest that unofficial message sources are an important component of education and outreach that should be examined, as previously suggested (Handmer 2001; Parker and Handmer 1998). If agencies provide better information about how to plan trips that avoid floods, such information would likely be propagated among social groups. The widespread use of social media could facilitate these efforts, though multiple channels will be necessary to capture different preferred modes of communication. Although this study found little evidence of risk attenuation, this result may be due to survey design that did not address attenuation specifically as well as the likelihood that those who took the time to respond to the survey are already more concerned about floods, representing a self-selection bias.

Similar to Drobot et al. (2007) the current study shows no statistically significant difference in reported crossing behavior among women and men, who admit to driving into floodwaters at approximately equal rates. However, there are gender differences in self-efficacy and the relative influence of specific situational factors, particularly the availability of an alternate route. The present study design does not permit analysis of whether males are more willing to drive into more dangerous flood conditions (Pearson and Hamilton 2014), which along with higher exposure rates would explain the higher proportion of males among those who have perished in floodwaters (Ashley and Ashley 2008; Coates 1999; Diakakis 2016; Diakakis and Deligiannakis 2013, 2015; FitzGerald et al. 2010; Franklin et al. 2014; Jonkman and Vrijling 2008; Jonkman and Kelman 2005; Kellar and Schmidlin 2012; Maples and Tiefenbacher 2009; Paul et al. 2018; Pearson and Hamilton 2014; Peden et al. 2016, 2017; Pereira et al. 2017; Salvati et al. 2018; Sharif et al. 2012; Terti et al. 2017). However, the present study shows that males and females weigh situational factors differently in their decision-making, with nuances that should be further examined to better understand gender differences in risk perception and risk-taking behavior.

7. Conclusions

This study reveals some alternative and complex rationalities for why a motorist might "drive into danger" and attempt to cross a flooded roadway. Responses to questions eliciting the cultural factors examined in this study—trust, self-efficacy, and social incorporation—suggest a strong link to a desire for more detailed information about the degree of present danger and how to proceed safely. They also demonstrate that people drive through flooded roadways even though they know it is dangerous but that they do not do it out of disregard for the warning or personal safety. Those who have driven through do not do so every time they encounter floodwaters, indicating that the situational context matters and not just individual risk perception or predisposition to take risks. Certainly, some people are more reckless or less knowledgeable about flood danger, but even those who "know better" are willing to drive through under certain circumstances. Instead of dismissing crossing behavior as irrational in every scenario, flood risk managers should seek to understand the reasoning behind it and work to change the circumstances that lead to crossing behavior.

While factors such as the successful prior crossing of another vehicle and the vehicle size influence motorists' decisions in expected ways, other factors related to gender, trust in official messages, and incentives and deterrents for crossing behavior do not. The fact that respondents show a high degree of trust in flood warnings and rate danger as the strongest deterrent shows that outreach is already a critically important component of flood hazard management. However, education alone is not likely to prevent drivers from entering flooded roadways, especially if drivers cannot tell whether conditions are currently unsafe or if they do not know an alternate route. Drivers seek further information by observing the environment and discussing floods within their social networks. Further decision support could come in the form of better signaling at specific low-water crossings and alternate route maps.

The results of this study raise several questions for future research. Since people react differently depending on the situation, it would be useful to have a better understanding of risk threshold, with a way to weigh environmental factors such as water depth and velocity with the perceived urgency of the trip. A study that effectively captures a diverse population could examine whether the importance of certain cultural and situational factors differs among demographic groups other than gender. Future research should also further examine how people use flood-related information. Since environmental cues play an important role in decision-making, further studies could examine which cues are useful for assessing danger and which encourage dangerous behaviors because of misguided assumptions. In addition, future studies should examine how people exchange flood information among their social groups and consider how these processes could be harnessed for education and outreach programs. In particular, such studies should consider how social media and other mobile telephone apps are or could be used to share information about flood conditions and alternate routes, especially in such a way that motorists have easy access to both the warning and the solution.

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