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The Effects of Flood Warning Information on Driver Decisions in a Driving Simulator Scenario

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THE EFFECTS OF FLOOD WARNING INFORMATION ON DRIVER DECISIONS IN A DRIVING SIMULATOR SCENARIO

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ABSTRACT

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Flood warnings are a type of risk communication that alerts the public of potential floods. Flood warnings can be communicated through mobile devices and should convey enough information to keep the user safe during a flood situation. However, the amount of detail included in the warning, such as the depth of the flood, may vary. The purpose of this study was to: (a) extend our prior research on flood warnings by recreating the written driving scenarios into the driving simulator; (b) deepen the understanding of human decision-making in risky situations; and (c) investigate how to best inform drivers of floods by design to keep them protected. We examined the effects of flood warning information on the actions taken by drivers in various driving scenarios in a driving simulator. Participants were tasked to drive to a restaurant after receiving instructions and a type of flood information warning during each scenario (flood, no flood, flood of 6 inches, flood of 6 inches maximum). Their actions taken, trust in the navigation system, understanding of the situation and scenario, and perceived risk were measured for each type of flood information warning. We found that participants accepted the alternate route more when in a scenario with a flood present compared to the no-flood scenario. The level of detail of the warning did not influence the actions taken. These results deepened the understanding of human decision-making and can guide future flood warning designs to keep drivers protected from flooded roadways.

This thesis is dedicated to my greatest supporters and parents, Julia, Carlos, and Monica.

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NOMENCLATURE

GPS	Global Positioning System
MSSQ	Motion Sickness Susceptibility Questionnaire

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CHAPTER 1

INTRODUCTION

Floods can result in costly losses, such as infrastructure, property, resources, and lives. Risks of floods should be communicated to stakeholders to avoid these potential losses. Successful risk communication for hazardous situations can prevent costly damage and save lives. Risk communication can inform the public about potential floods through flood warnings. Flood warnings are a type of risk communication that alerts the public about possible floods. Flood warnings can vary in the amount of detail that is included in the warning (Rollason et al., 2018). Some warnings tell the user the depth of the flood or where emergency resources can be found, whereas others may only tell users that a flood is possible for their area (Leelawat et al., 2013). Flood warnings can also differ in how they are communicated to the public (Feldman et al., 2016). In the past, flood warnings were popularly propagated through news network radio broadcasts and through The Weather Channel, but are now being transposed through other means, such as social media and weather applications. Mobile applications are especially useful for conveying flood information to drivers due to their accessibility and abilities (Leelawat et al., 2013). The objective of this study was to investigate factors that affect drivers' understanding of and action to a flood warning given by their mobile navigation application in a driving scenario. The contribution of this study was to extend our prior research on flood warnings by increasing the external validity by simulating the driving scenario in a driving simulator rather than a written passage, deepen the understanding of human decision-making of drivers when faced with a flooded roadway, and investigate how to best inform drivers of floods to encourage protective driving responses.

1.1 Risk Communication

Risk is defined as "the extent to which there is uncertainty about whether potentially significant and/or disappointing outcomes of decisions will be realized" (Sitkin & Pablo, 1992, p. 10). Risk in a relationship is found to be a significant contributor to trust, the willingness to take risks, in working with the other party (Mayer et al., 1995). Since risk is difficult to objectively quantify due to its complexity, a subjective measure of perceived risk may be used instead (Mitchell, 1999). Chang and Chen (2008) found trust and perceived risk to act as mediators on the impact of online store environment cues on purchase intent. Effective risk communication can help appropriately calibrate perceived risk and build trust (Aakko, 2004).

Risk communication is a key factor in assisting people to make safe and appropriate decisions based on the risk at hand. Risk communication has several main objectives: to inform and educate users about the risk in general, to encourage risk-reduction behavior and protective actions, to provide disaster warnings and emergency information, and to involve the public in risk management decision-making and conflict resolution (Covello et al., 1986). There are several problems associated with risk communication, including (a) message problems, such as a high level of scientific complexity in the message, (b) source problems, where the sender of the message lacks trust or credibility, (c) channel problems, such as selective and biased reporting, and (d) receiver problems, where the individual inaccurately perceives the risk through the message (Covello et al., 1986). Warning messages should answer seven questions that address these problems: who is issuing the warning, what is threatening, what exact geographical area is threatened, when is it coming, how probable is the event, are there high-risk locations, such as people in automobiles that require special actions, and what specific protective actions should be taken (Drabek, 1999).

There are two general approaches to risk communication, the information-processing approach, and the mental model approach (Chen, 2020). The information-processing approach emphasizes the inclusion of the human as a part of the communication system, whereas the mental model approach focuses on how the user thinks about and understands the system through their mental models (Chen, 2020). A mental model is defined as "a mental structure that reflects the user's understanding of a system and therefore is a source of expectancies about how a system will respond" (Wickens et al., 2013, p. 236). Mental models influence people's decisions, develop with individual experience with the system, and may be incomplete and incorrect (Chen, 2020; Wickens et al., 2013). The influence of risk communication depends on several factors and their interactions including the characteristics of the receiver, the source of the message, and the content of the message (Breakwell, 2000). For flood warnings specifically, the mental model approach can help designers understand what their target audience already knows about floods and how they respond to them, as well as any gaps in their knowledge that may need to be addressed (Lazrus et al., 2016).

Risk communication can be at various levels of detail to accommodate the user's needs. For example, in studies of communicating risks associated with using mobile applications, Jorgensen and colleagues (2015) propose a multi-granularity approach to risk communication. This multi-granularity approach to risk communication is multidimensional and varies in the amount of detail or information that is included in the risk communication message (Jorgensen et al., 2015). The most abstract level is an overall summary of the risk in general, which lets the user quickly understand the overall risk. Examples at this level include risk summary scores developed by Gates and colleagues (2014) and the privacy grading of applications (Kelley et al., 2013). The most detailed level is the detailed risk information, which can be conveyed through

application permissions in the current Android interface. At the intermediate level, risk information is integrated from multiple sources which lets the user assess the risk along several dimensions (Chen et al., 2018; Jorgensen et al., 2015).

The multi-granularity approach can relate to both the information-processing approach and the mental model approach. For the information-processing approach, the different levels of detail may affect how the human interprets the warning from the communication system and processes the information. For example, if a warning contains a high level of detail with technical jargon, then experts in the field may comprehend it more while laypeople may rely on their own beliefs rather than trying to understand the warning. On the other hand, if the warning contains the minimum level of detail, then experts may only need a little attention to process and understand the message while laypeople may need more attention to comprehend it. For the mental model approach, the levels of detail may affect how they apply their mental models and inform us how their mental models are structured. For example, if a person responds more to a warning with more detail than less detail, then that means a high level of detail is needed for their mental model to be applied and that their models are detailed. On the other hand, if they respond more to less detailed warnings than more detailed, then that means only basic information is needed for their mental models and that the models are rougher and more abstract.

1.2 Flood Risk Communication

Flood risk communication is a type of risk communication that aims to educate the public of a potential flood and to aid the public to make safe decisions to protect themselves and their belongings from a possible flood situation (Mileti, 1995). To be effective, flood warnings should convey their source and channel of communication, ensure message consistency, accuracy,

clarity, and certainty, and contain sufficient information such as guidance, frequency of the risk, and risk location (Mileti, 1995).

Flood risk communication can be conveyed through auditory and visual warnings, often with the assistance of maps. Flood hazard maps typically contain real-time information, water depths, and the probabilities of flood occurrence, and use the color blue to represent water due to the natural association (Hagemeier-Klose & Wagner, 2009). Rollason and colleagues (2018) found that current risk communications fail to meet the user's needs and developed four prototypes of flood hazard maps containing information on when and how flooding may occur with the input of laypeople. Liu and colleagues (2017) examined whether maps improve the public's comprehension of crisis and disaster information in Wireless Emergency Alerts, tweets, and long-form messages. They found that the majority of the information in a flood warning is carried by the warning itself rather than the map, although the map slightly increases warning comprehension and potential compliance with the recommended actions stated in the warning (Liu et al., 2017).

1.3 Mobile Devices in Flood Risk Communication

Mobile devices can also relay flood risk communication, especially enabled by the increasing popularity of mobile devices. Cumiskey and colleagues (2015) found that mobile services are the preferred means of warning communications compared to television for flash flood warnings. They also found that people preferred voice short messaging service (SMS) and interactive voice response (IVR) because of easier accessibility and understanding of the flood information (Cumiskey et al., 2015). Specifically for mobile devices, Leelawat and colleagues (2013) compared the different information that various weather mobile applications provided to users and found that people downloaded mobile weather applications that provide information

related to flood warnings, flood-area monitoring, and flood road monitoring information. Based on these findings, Leelawat and colleagues suggest that flood mobile applications should let users know where the flooded areas are, safe places the users can evacuate to, and should help users gather pertinent information to survive during flood situations.

Mobile navigation applications have grown in popularity and usage with the rise in mobile devices. These services help users route their journey from point A to point B. Some of these applications, such as Google Maps, even notify the user if their destination location will close within the hour of arrival (Allen, 2015), or if there is a police speed trap nearby (Hayes, 2019). Waze, another mobile navigation application, began a pilot program in Norfolk, Virginia to help drivers avoid flooded roads in real-time by partnering with FloodMapp, the winner of the RISE Urban Mobility Resilience Challenge, to forecast floods (Staff, 2022). However, there is a lack of literature involving these warning notifications by mobile navigation applications.

1.4 Effect of Past Flood Experiences

There have been mixed findings concerning the effect of a person's past flood experience on their flood risk perception. Risk perception may differ between individuals due to certain cognitive biases such as overconfidence, the illusion of control, and the belief in the law of small numbers when they draw conclusions from a limited number of informational inputs (Simon et al., 2000). When it comes to flood risk perception, there is a paradox regarding the relationship between past flood experience and perception of the danger of a flood. Relying on one's limited past flood experience can lead to different flood risk perception. For example, in a meta-analysis, Wachinger and colleagues (2013) showed that people with direct flood experience tend to overestimate the danger; however, if they have experienced a flood with no personal damages, then they are more likely to believe that future similar events will unlikely affect them, indicating

decreased risk perception. Similarly, Kellens and colleagues (2011) found that past flood experience with personal damages contributes to flood risk perception, as measured through a questionnaire containing scaled items regarding storm surges and coastal flood risks; individuals who have past flood experience have a higher perceived level of flood risk. Mol and colleagues (2022) also found that people who experience a flood disaster in virtual reality invested more in risk-reducing measures; those who have recently experienced a flood disaster in virtual reality have a higher perceived risk for floods. In addition, Burningham and colleagues (2008) found that previous flood experience is the second most influential factor in predicting flood risk awareness (comprised of awareness of flood-risk areas, flood warning systems, and appropriate actions to take in a flood event), and that those with more flood experience were more aware of their flood risk. Beyond risk perception and awareness, studies have also shown that past flood experience influence participants' reported behavior when faced with a flooded roadway. Pearson and Hamilton (2014) found that past behavior in a flood situation has an influence on whether a person will drive through a flooded roadway or not given a written driving scenario; people with previous experience of driving through flooded roadways are more likely to drive through a flooded roadway again. Across the above discussed studies, past flood experience influence flood risk perception, awareness, and reported behavior.

However, Drobot and colleagues (2007) found that, in a hypothetical driving scenario, past flood experience had no significant influence on whether a person reported that they would drive through a flooded roadway or not. This study differs from the other studies discussed above in that participants were told there were approximately 18 inches of water on the roadway. Among those studies, Wachinger and colleagues (2013), Kellens and colleagues (2011), and Burningham and colleagues (2008) did not include the water depth in their studies. Pearson and

Hamilton (2014) included water depths of 8 inches and 24 inches in their study. It is likely that by including a single, relatively deep depth of water in Drobot and colleagues' study, participants may have been less likely to drive through the flooded roadway, regardless of their past flood experience. In addition, Drobot and colleagues measured past flood experience in a similar way to Burningham and colleagues, which included questions asking about experience with the flood itself, not considering personal damages or past behavior. It is also possible that the flood experience only affected flood awareness and not reported behavior.

1.5 Effect of Gender

There have also been mixed findings regarding the effect of gender on flood risk perception and related behavior. Kellens and colleagues (2011) found that gender contributes to flood risk perception; females have higher perceived levels of flood risk than males. Drobot and colleagues (2007) found that gender effects were present in affecting whether a person would drive through a flooded roadway or not for only one group of their participants; males self-reported to drive through a flooded roadway more often than females. However, Burningham and colleagues (2008) found that there was no significant difference in flood risk awareness between males and females. Mol and colleagues (2022) also found that there was no significant difference in gender on perceived risk when presented with a flood in a VR setting. Similarly, Coles and Hirschboeck (2020) found no statistically significant difference between males and females in crossing a flooded roadway. In sum, given these findings, it is important to consider gender when predicting one's decision-making and responses when faced with a potentially flooded roadway.

1.6 Flood Depth

The risk of driving through a flooded roadway depends on the depth of the flood water and the height of the vehicle's ground clearance. There are several flood depth thresholds considered for risky travels. While ambulances are considered capable of crossing through 60 centimeters of flood, approximately 2 feet of water (Kramer et al., 2016; Gori et al., 2020), in practice, they restrict their threshold to 25 centimeters to minimize the risk of vehicle malfunctioning, approximately 10 inches (Johnson & Yu, 2020). This 25-centimeter flood threshold is used in other studies focusing on emergency service vehicles (Coles et al., 2017; Green et al., 2017; Dawson et al., 2011). However, there is a gap in the literature when it comes to the depth threshold for normal passenger vehicles, such as sedans and Sports Utility Vehicles (SUVs).

Water depths of 12 inches can cause normal passenger vehicles, such as sedans and SUVs, to float, and 2 feet of water can sweep them away (Gerhardt, 2019). If water reaches the bottom of the car, it can set off a chain reaction that may damage the engine of the vehicle (Gerhardt, 2019). Normal passenger cars have a much lower ground clearance, which is the distance between the ground and the bottom of the vehicle body, than emergency vehicles that are tailored for driving through rough terrain. The typical ground clearance for a sedan vehicle is 4-6 inches and 6-8 inches for SUVs (C., 2021). Only a few studies varied the water depths when investigating driving behavior (Hamilton et al., 2016; Pearson & Hamilton, 2014). For example, Hamilton and colleagues used 20 centimeters (roughly 8 inches) and 60 centimeters (roughly 24 inches) for flood depths in their study investigating individuals' beliefs to drive through flooded roadways. They found that participants who were willing to drive through 20 cm of flood and those who were willing to drive through 60 cm of flood both held the belief that driving through

the floodwaters would have the outcome of them reaching their destination and that other family members would approve their decision to drive through the floodwaters (Hamilton et al., 2016).

Among the different types of floods, flash floods can happen quickly and without warning, catching people off-guard and unprepared, especially when they are driving. Drivers may need to make decisions (e.g., whether to drive through the flood or not) and take action quickly when faced with a flooded roadway during a flash flood. Pearson and Hamilton (2014) investigated the factors that influence drivers' decisions regarding flooded roadways and found that past behaviors of driving through a flooded roadway, in general, has an influence on if they will drive through a flooded roadway again. Similarly, Coles and Hirschboeck (2020) found that larger vehicle size, lower trust in the warning messages and their sources, the lack of alternate routes, and the lack of barricades or signs are all factors that increase a person's decision to cross a flash-flooded roadway. Their findings are consistent with an earlier study by Thomas and Walton (2008), who found that SUV drivers are more likely than car drivers to believe in the apparent, but false, safety benefits of larger vehicles. It is also possible that people drive through the flooded roadway because they underestimate the risk of the flood. Morss and colleagues (2016) found that people underestimate the level of risk that forecasters intended to convey when a flash flood warning is issued, especially when entering flash-flood waters on foot or in a car. Taken together, a number of factors can influence drivers' decisions regarding flash-flooded roadways.

1.7 Pilot Study

In a pilot experiment (Garcia et al., 2021), we examined the effect of time pressure and flood warning type on intended actions in a written driving scenario presented to participants. Time pressure was hypothesized to affect how people interact with the warning system. That

study employed a 2 (time pressure: with or without) x 4 (flood details: yes flood, no flood, yes flood of 2 inches, yes flood of 4 inches) design. Each participant was randomly assigned to one of eight different flood scenario conditions. Participants were asked questions measuring their understanding of their situation, their perceptions of time pressure in their situation, the actions taken based on their scenario, and their trust in the navigation system, through an online survey. The pilot study was conducted with images of Waze (Version 4.64) navigation routes and text notifications, such as their next route instruction, flood warning, and that Waze had found an alternate route (Waze, 2021). We found that participants displayed avoidant responses when given any type of flood warning indicating the presence of a flood and that they tended to display risky responses with time pressure. However, the main effect of time pressure was not statistically significant. The pilot study was only through a survey, although participants were asked to answer questions as if they saw the messages while driving, did not measure what people thought the depth was for the general flood warning in the yes-flood condition, and only had a maximum of 4 inches of flood water depth.

A second pilot experiment (Garcia et al., 2022) showed that participants in the general flood condition assumed roughly 6 inches of flood water depth, which is substantially greater than the 4 inches stated and presented in the first pilot experiment (Garcia et al., 2021).

1.8 Current Study

Following the pilot experiments (Garcia et al., 2021; Garcia et al., 2022), the current study investigated how people perceive risk, trust, and make decisions, and the influential factors, based on information provided by flood warnings via a mobile navigation application in a simulated driving environment. Trust was defined as a multi-dimensional, intrinsic relationship between a subject and an object with potential uncertainty that may change over time

(PytlikZillig & Kimbrough, 2016; Jian et al., 2000). In this case, the subject was the person, and the object was the mobile navigation application. Jian and colleagues found that people perceive the concepts of trust similarly between general trust, human-human trust, and human-machine trust. The trust measure used is based on an empirical analysis of multiple components of trust rather than theoretical concepts of trust (Jian et al., 2000). The factor we focused on was the level of detail of the flood risk communication. Specifically, this driving simulator experiment tested whether types of flood risk communication (abstract vs. detailed) influenced driver decisions. The abstract information condition provided drivers with only information about the presence of flooding without specific flood water depth while the detailed information condition provided drivers with specific flood water depth (e.g., 6 inches) in addition to information about the presence of flooding. The perception of the flood depth would be the same, but the details and presentation of the information of the flood depth differed. It is possible that participants in the pilot experiment did not change their route between the 2-inches and 4-inches flood conditions because the depth levels were less than 6 inches, which was found to be an assumed level of flood driving threshold. Thus, their route decisions should have been similar between the abstract and detailed flood conditions when the detailed flood condition was at 6 inches.

Compared to previous studies, our current study included both visual (Liu et al., 2017) and auditory warnings through a mobile device (Cumiskey et al., 2015) to convey warnings about floods of different depths (Pearson & Hamilton, 2014; Hamilton et al., 2016) while it statistically controlled past flood experience (Pearson & Hamilton, 2014) and gender (Kellens et al., 2011; Drobot et al., 2007). Moreover, we used a driving-simulator-based driving scenario, whereas most previous studies used written driving scenarios or questionnaires (Garcia et al., 2021; Pearson & Hamilton, 2014; Hamilton et al., 2016; Coles & Hirschboeck, 2020). The

driving simulator was a good alternative to a real drive because we could control the driving environment and present a hazardous situation without placing the participant in danger while still collecting valid participant actions (Underwood et al., 2011; Kaptein et al., 1996; Meuleners & Fraser, 2015).

Currently, there are not many studies that investigate flood risk communication on mobile devices with a driving scenario. Thus, utilizing a driving simulator for this study was a novel approach since no other previous research has used a driving simulator for this research topic (Garcia et al., 2021; Pearson & Hamilton, 2014; Hamilton et al., 2016; Coles & Hirschboeck, 2020). In this regard, there were also not many studies that give alternative routes, other than Coles and Hirschboeck's. To our best knowledge, this study was the first to incorporate both visual and auditory flash flood warnings from mobile navigation applications in a driving-simulator-based scenario.

The purpose of this study was to investigate factors that affect road users' understandings and actions given a flood warning, specifically, a flood warning through a mobile navigation application (i.e., Waze), in a driving simulator scenario. The present study extended the pilot study by recreating the scenarios on a driving simulator where participants were driving to a destination. This setting allowed us to test how different flood information affects participants' responses when they learn that there is an expected flood on their route in a more naturalistic setting, thus increasing the external validity of the study. By using the driving simulator, the participants were asked to control the vehicle in a dynamic, realistic driving environment while presented with flood information via a mobile device both visually and aurally. This simulated environment likely elevated the cognitive load of drivers by inducing urgency of the task and thus influenced their processing of the flood information and route choices unlike in the online

experiment with indefinite time to consider different route alternatives. In addition, the self-reported actions given through the online questionnaire may have differed from real-world actions, even though they both reflect the same choices and scenarios (Hagger et al., 2015). For these reasons, the driving simulator engaged the participant more actively in the scenario compared to the online questionnaire where a disconnect may have existed, and thus their actions were more like what they would do in real life.

Finally, we explored the influences of past flood experience, gender, perceived risk, and trust toward the mobile navigation application system on driver decisions within the theoretical framework of the mental model approach to risk communication (Chen, 2020). Based on the level of detail of the flood warning, how do people apply their mental models and what implications does it have on the structure of mental models? Did they rely more on the navigation warning or their own knowledge based on the flood images given? How did past flood experience, gender, and perceived risk influence their responses? In addition, given our prior results showing no significant effect of time pressure, the present study no longer manipulated time pressure.

1.9 Hypotheses

1.9.1 Hypothesis 1

Participants were expected to keep the same route less often when the flood warning informs them of a flooded roadway than when the flood warning informs them there is no flood expected on their route. This hypothesis was based on our pilot study which found participants to continue on the original route less often when given a flood warning compared to when they received a warning that there was no flood expected on their route (Garcia et al., 2021). It was acceptable for participants in the no-flood condition to keep the same route their mobile

navigation application suggested to them since there was no expected danger on their route. But for participants that did receive a flood warning indicating that there was a flood expected on their route, then keeping the same route would lead to a dangerous situation, which drivers should want to avoid.

1.9.2 Hypothesis 2

Participants were expected to keep the same route less often when the flood warning contains information of depths of flood water than when the flood warning informs them there is no flood expected on their route. This hypothesis was based on our pilot study which found participants to continue on the original route less often when given a flood warning with information of flood water depths compared to when they received a warning that there was no flood expected on their route (Garcia et al., 2021). The additional information of the depth of the flood lets drivers know both the information that there was a flood on their route and the depth of the flood. Since this type of warning conveyed there was a flood on their route, the rationale behind this hypothesis was similar to that of Hypothesis 1.

1.9.3 Hypothesis 3

Participants were expected to keep the same route less often and display more flood avoidant responses when the flood warnings provide general information that there is a flood on their route than more detailed flood information that includes the depth of the flood water on their route. This hypothesis was based on our pilot study which found participants to continue on the original route less often and display flood avoidant responses when given a general flood warning than when given a flood warning containing the flood depth information (Garcia et al., 2021). In a follow-up study, Garcia and colleagues (2022) found that participants estimated the depth of the flood to be, on average, 6 inches, when participants were given the general flood

warning information. Participants overestimated the depth of the flood when the flood depth information was not presented, leading to risk-avoidant driving responses.

1.9.4 Hypothesis 4

Trust in the navigation system was expected to increase as the level of detail increased in the flood warnings. Participants would trust the flood warnings with more detail, such as the floodwater depths, more than the flood warnings with less detail, such as the general statement of whether there was or was not a flood expected. This hypothesis was an exploratory hypothesis since there was no literature regarding trust in flood warning details. However, trust was found to be a mediator for the effect of presentation details on consumer judgment and evaluation of the AI; specifically, trust was found to be greater for precise information rather than imprecise (Kim et al., 2021).

CHAPTER 2

METHOD

2.1 Participants

A total of 93 participants were recruited through Old Dominion University's online research participation system (SONA; odupsychology.sona-systems.com). Eligible participants were adults 18 and older who had a driver's license with normal or corrected-to-normal vision and hearing and had passed the motion sickness screening. These criteria resulted in a total of 82 eligible participants. The mean reported age was 20.02 years (N = 82, SD = 3.94). Participants reported their gender as male (n = 25) or female (n = 57). Participants reported their ethnicity as Caucasian, Non-Hispanic (n = 31), Black, Non-Hispanic (n = 29), Native American/Alaskan (n = 1), Asian/Pacific Islander (n = 2), Hispanic (n = 9), or Other/Unknown (n = 10). Participants also reported their highest level of education as less than high school (n = 2), high school graduate (high school diploma or equivalent including GED) (n = 25), some college but no degree (n = 52), or associate degree in college (2-year) (n = 3). The mean reported age participants first obtained their license was 16.27 years (N = 82, SD = 2.92). Participants received research credits towards a course for participating in this 60-minute study.

2.2 Design

The study used a within-subjects design, so each participant experienced all four flood-information-type conditions. The independent variable was the type of flood warning information with four levels (flood, no flood, flood of 6 inches, flood of 6 inches maximum). The type of flood information reflected the level of granularity for conveying flood information. The flood and no-flood conditions communicated a binary categorization of the flood with **an**

abstract level of information to communicate the status of the hazard. For example, the yes-flood condition warning stated, “There is a flood expected ahead.” The flood of 6 inches and flood of 6 inches maximum conditions of flood information communicated **a detailed flood warning** with both the presence of a flood and the depth of the flood. For example, the flood of 6 inches warning stated, “There is a flood of 6 inches ahead.” This depth was determined by the average depth participants reported the floodwater to be in the general flood condition from our second pilot study (Garcia et al., 2022). The difference between the flood of 6 inches and flood of 6 inches maximum condition was the additional phrasing of the depth as a maximum of 6 inches, which may have had an influence on the participants’ risk perception.

There were three dependent variables (DVs). The first DV was the action taken after the warning (if they continue with the original route and drive straight through a possible flood, accept the alternate route and turn to avoid a possible flood, find a new route to avoid a possible flood, wait for the flood to go away, or go back the road they just were on). The second DV was participants’ trust in the navigation system adapted from the Checklist for Trust between People and Automation by Jian and colleagues (2000). The third DV was the participants’ understanding of the warning, measured by questions asking them about their scenario and the warning that they received.

2.3 Materials

Four unique flood conditions, following a similar structure, were programmed in STISIM Drive (Build 3.20.03), and presented through a 27-inch Dell monitor (1920 x 1080, 32-bit, 60 Hz) paired with the Logitech G27 Racing Wheel and steel gas, brake, and clutch pedals for this study. Within these conditions, participants were asked to manually drive to a local restaurant, and images taken from Waze (Version 4.80) were included to show the route that the navigation

system plans out, as well as the warning that the system conveys about the flood (Waze, 2022). All four conditions of flood information were presented to each participant, counterbalancing the order with a Latin square design.

Before the flood conditions were presented, the participant first took the Motion Sickness Susceptibility Questionnaire (MSSQ; see Appendix A) to determine if they had or were likely to experience simulator sickness from the driving simulator (Golding, 2006). The MSSQ asked if the participant had previously experienced motion sickness as a child and in the past 10 years for different modes of transportation and experiences, such as boats and carnival rides. They then took a practice drive in the simulator to familiarize themselves with the apparatus. This simulation placed the participant on the road and had them accelerate, decelerate, follow GPS instructions at several intersections, including turning at two of them, and view what a flood looked like in the simulator (see Figure 1). The practice drive took approximately 3 minutes if following the posted speed limit signs and traffic signals.

Figure 1

Flood Example

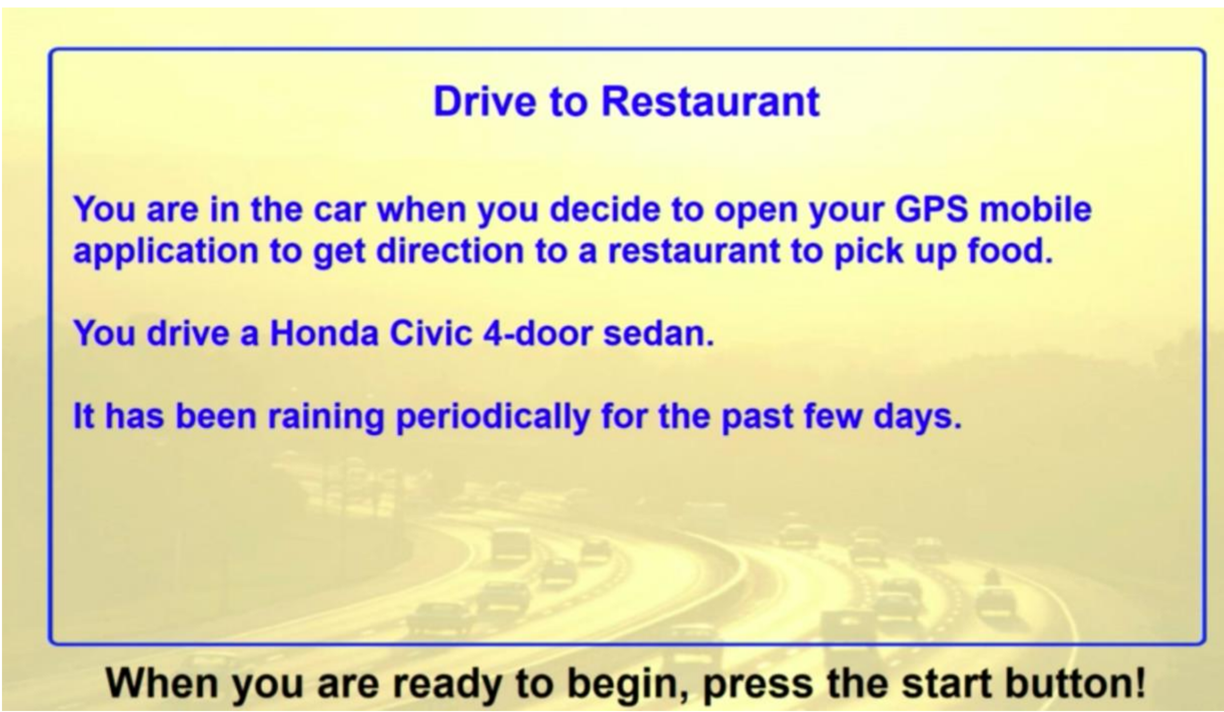
Note. This scenario is shown at the end of the practice drive.

For the flood conditions, the participants were first instructed that it had been raining periodically for the past few days and they were to drive to a local restaurant to pick up food in their Honda Civic sedan car (see Figure 2). The Honda Civic sedan was selected because it was a commonly known mid-sized passenger vehicle. They then received a visual display (see Figure 3) giving the driver directions to a local restaurant to pick up food. The visual display showed the user's location and a mapped route to their destination along with an estimated arrival time including both a driver view track-up map and an overview north-up map. After these two displays, the participant was placed on the road to start their drive to the destination. During the

drive, the navigation system provided directions (see Figure 4) to the driver both visually on the vehicle's dashboard (see Figure 5), and auditorily, just like in the practice drive. The auditory directions read out the navigation instructions, such as, "At the next intersection, continue straight." The auditory directions ranged from 2 to 3 seconds in duration and were from Voicemaker.in (Version Beta), an online text-to-speech (TTS) converter which reads entered text using a female synthesized voice.

Figure 2

Driving Task Instructions



Note. The driving task was the same for all four flood simulations.

Figure 3

Waze General Directions

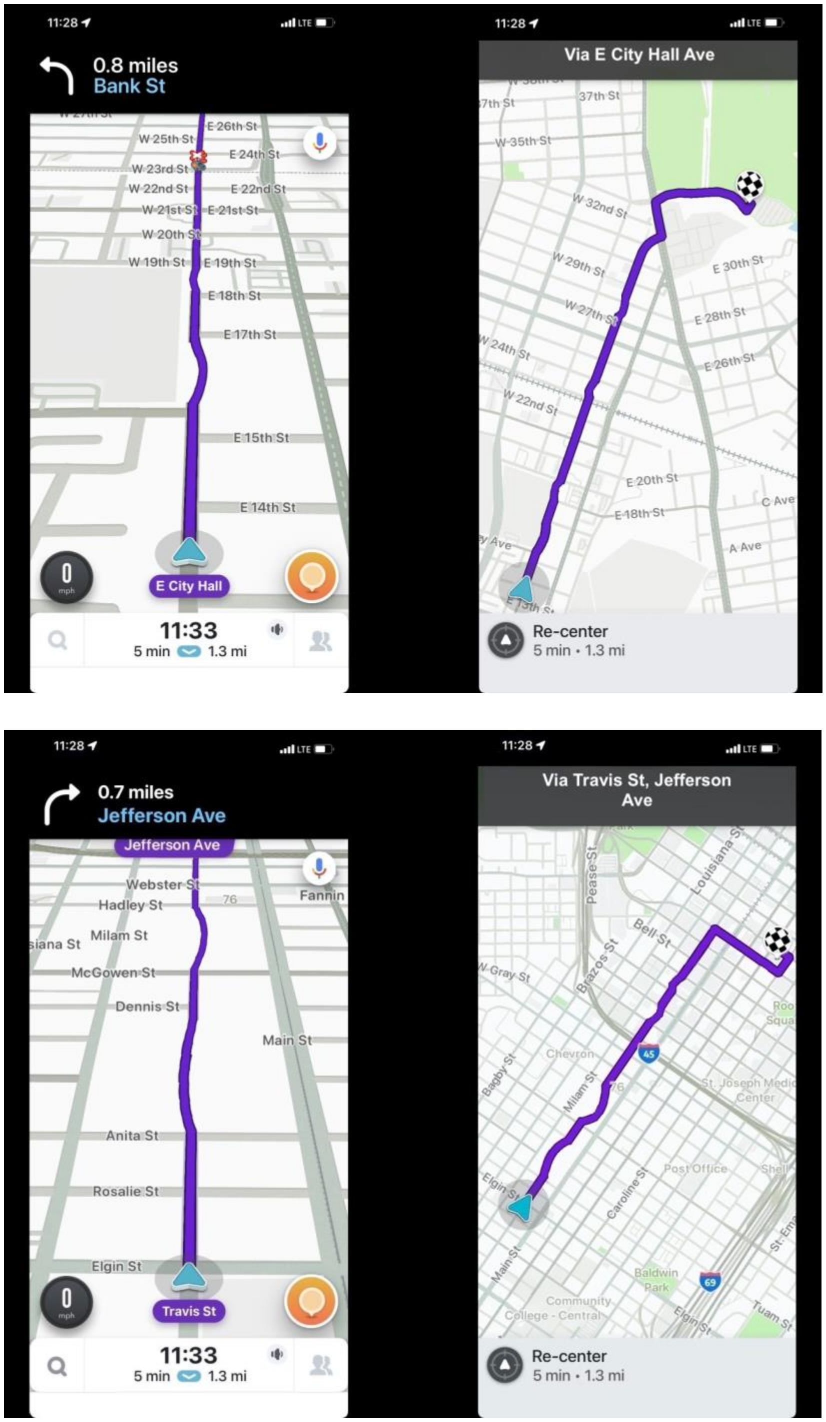
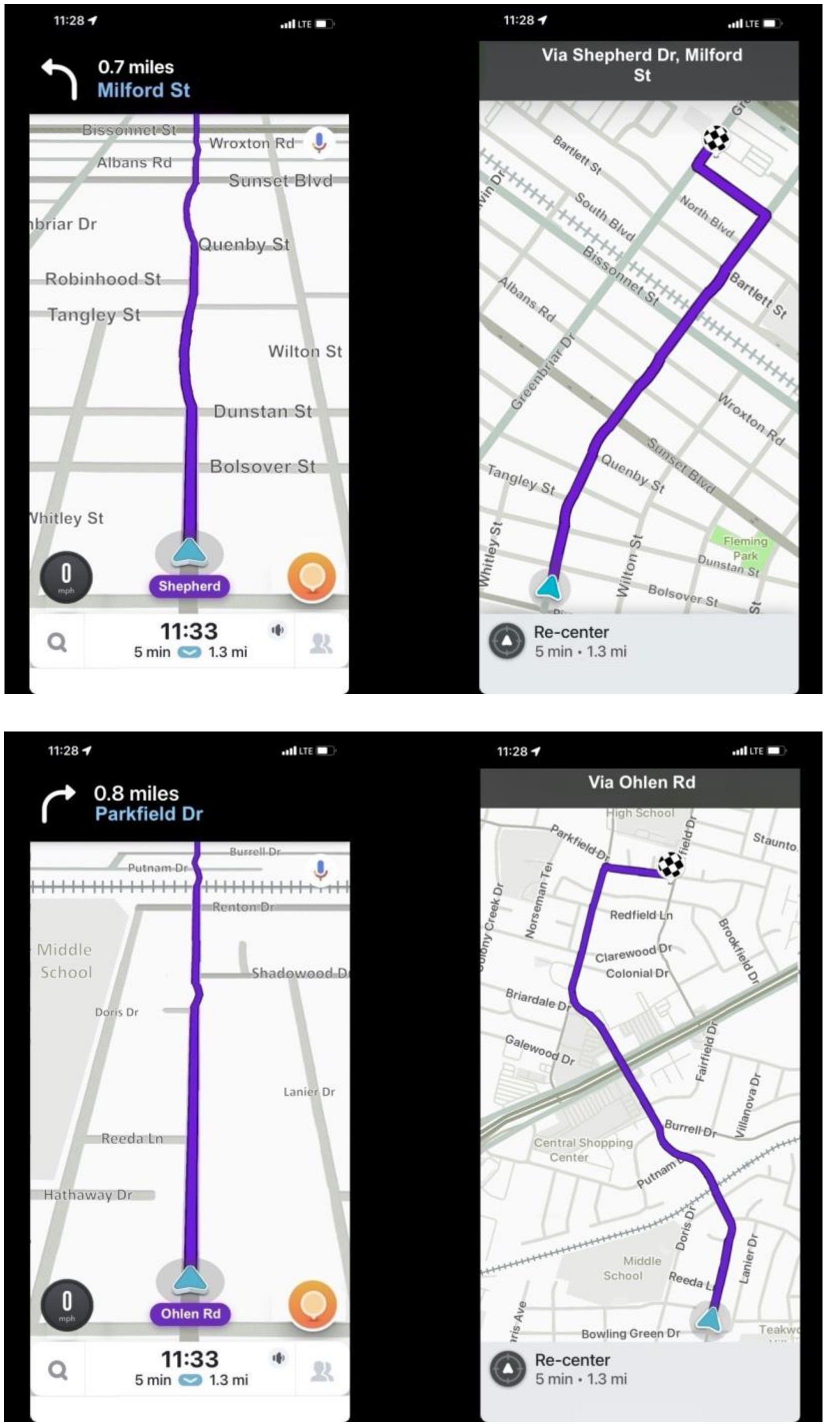


Figure 3 Continued



Note. From left to right: driver view track-up map of the route, and overview north-up map of the route. From top to bottom: visual display for flood, no flood, flood of 6 inches, and flood of 6 inches maximum conditions.

Figure 4

Navigation Directions

Note. From left to right: directions to continue straight, turn left, and turn right.

Figure 5

Navigation Directions on Dashboard

Note. Directions appeared on the dashboard before each intersection.

Towards the end of the drive, they received a visual and auditory warning about the flood situation on their route, possibly with the depth of the flood water (see Figure 6) on their dashboard in the same location where the navigation directions are displayed. These warnings relayed various flood information and details, depending on the experimental condition. The auditory warning read out the flood information presented in the image to the user. The auditory warning was 1.34 seconds in duration for the flood scenario, 1.42 seconds for the no-flood scenario, 2.21 seconds for the flood of 6 inches scenario, and 2.53 seconds for the flood of 6 inches maximum scenario, and all were created using Voicemaker.in (Version Beta). After the flood warning was displayed, the navigation system offered an alternate route visually (see Figure 7) on the dashboard and auditorily for the driver to take to avoid the flood ahead. The auditory alert was created using Voicemaker.in (Version Beta), lasted about 5 seconds in duration, and read out the directions to avoid a possible flood, such as, "An alternate route has been found. If you accept, turn right at the next intersection." The alternate route suggested the driver to turn right if they accepted the route for the flood and flood of 6 inches scenarios, and to turn left if they accepted the route for the no flood and flood of 6 inches maximum scenarios. Once the driver decided to either accept the alternate route and turn, or continue straight and possibly drive through the flood, the simulation ended. The four drives averaged to be about 5 minutes long, if following the posted speed limit signs and traffic signals, and ranged from 4 to 6 minutes in duration.

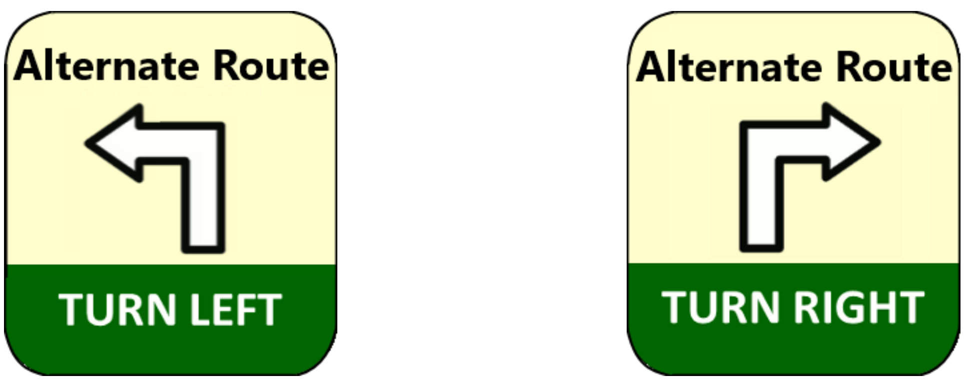
Figure 6

Waze Flood Warnings

Note. From left to right: flood, no flood, flood of 6 inches, and flood of 6 inches maximum.

Figure 7

Waze Alternate Route Navigation Directions



Note. From left to right: turn left at the next intersection to accept the alternate route, and turn right at the next intersection to accept the alternate route.

Once participants made their turning decision at the end of the simulation, they were directed to answer several questions testing their understanding of the warning, their perceived

risk of the scenario (Simon et al., 2000), and trust in the navigation system (Jian et al., 2000). After repeating this process for the other three flood conditions, they answered questions regarding their demographic information (Kyriakidis et al., 2015), driving history, and mobile navigation application usage. The questions testing their understanding of the warning asked specifically about their scenario condition and the warning that they received (see Appendix B). The questions about their perceived risk of the scenario were adapted to assess how participants perceive the level of risk associated with each driving scenario (see Appendix C). The questions regarding their trust in the navigation system were derived from Jian and colleagues and adapted specifically for the navigation system. These questions asked about how the participant sees the navigation system, such as deceptive, dependable, and if they can trust the navigation system (see Appendix D). The post-experiment questions included demographic information questions that were derived from Kyriakidis and colleagues and asked about the participants' age, gender, ethnicity, and education, as well as questions about driving history, and mobile navigation application usage (see Appendix E).

2.4 Procedure

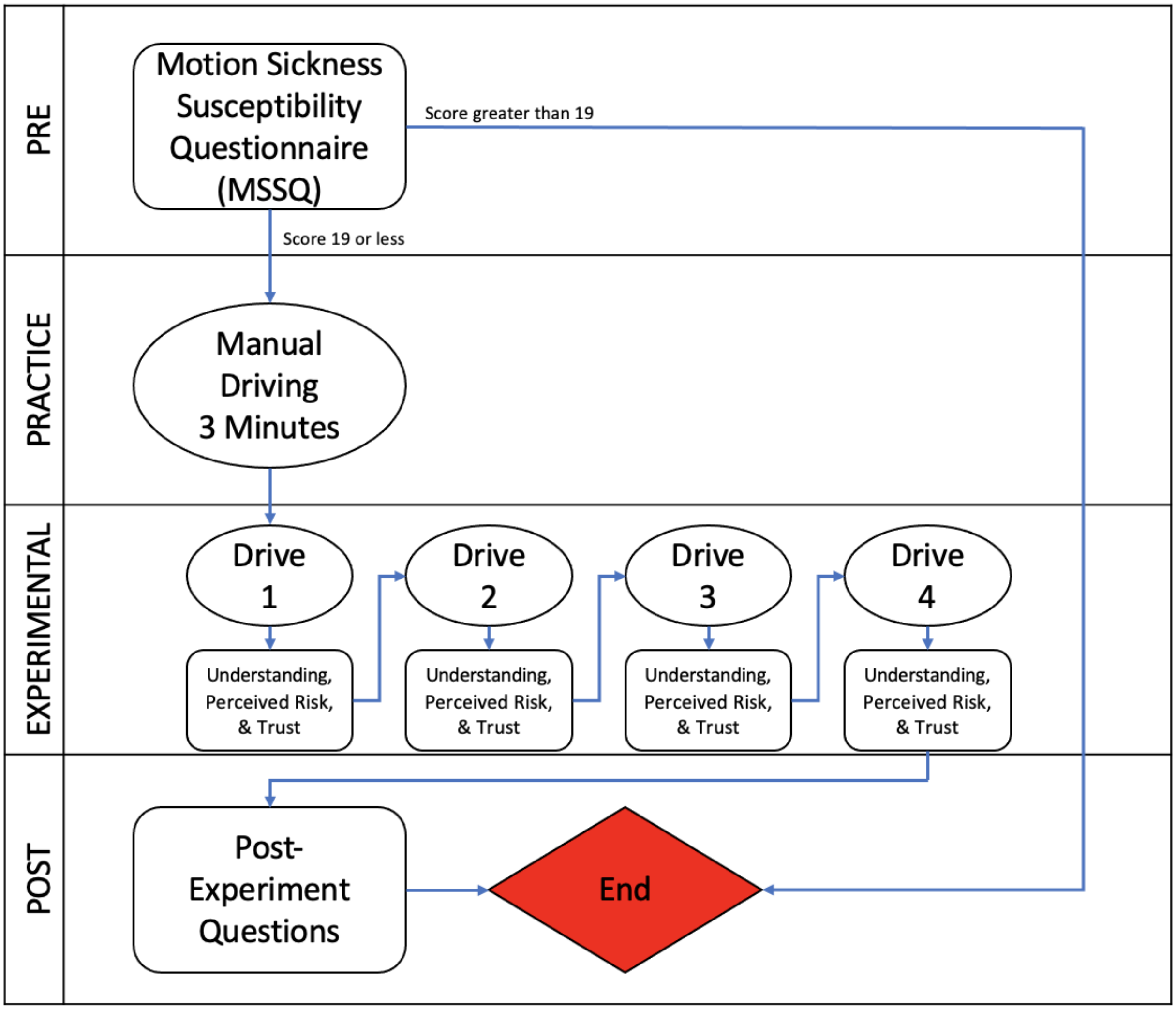
Participants were recruited through SONA during the 2022 Spring semester. The participants were individuals who had a SONA account and voluntarily signed up for the study. All participants were randomly assigned a presentation order for the four scenario conditions following a Latin square design.

The participants first read and completed the consent form. They then took the MSSQ to determine if they were likely to experience motion sickness from the driving simulator. If they scored over 19, they were not eligible for the study because of the high risk for simulator sickness and were dismissed from the study. For those who scored equal to or lower than 19, the

experimenter explained that they would complete several driving scenarios and answer questions about each of them. Participants first experienced a practice drive simulation so they could become familiar with the steering wheel and pedals in the simulator. Participants were told to drive as they normally would and follow all traffic rules, including following the posted speed limit, following traffic signals and signs, and so on. After finishing the practice drive, the experimenter started the first of the four flood scenarios. The experimenter had the participant read the driving task instructions (see Figure 2) aloud and told the participant to drive as they normally would and follow all traffic laws before starting the drive. Once the participant made their final turn decision regarding the possible flood and alternate route, they were directed to answer several survey questions testing their understanding of the warning, their perceived risk in the scenario, and their trust in the navigation system. After the participant answered these questions, the experimenter started the next flood simulation. This process was repeated until the participant had driven in all four flood conditions and had answered these questions for each scenario. After the last set of questions for the fourth scenario, they answered questions regarding their demographic information, past driving history, and mobile navigation application usage. After the post-experiment questions, the participant was thanked for their time and dismissed. The experimenter then assigned SONA credit to the participant. This process can be seen in Figure 8.

Figure 8

Procedure Flow Diagram



Note. Participants experienced all flood conditions and answered questions for each condition.

2.5 Measures

The first dependent variable was the participants' action taken after the warning, such as keeping the same route and continuing straight or accepting the alternate route and turning at the

intersection. Ideally, in any of the flood conditions, they would avoid the flood. If they were in the no-flood condition, then they would be able to keep the same route and continue straight. This measure was used to see if participants are willing to risk driving through flooded areas or not based on the flood warning received. Their actions were categorized as either risk-averse or risk-seeking. For example, driving through the flooded roadway would be risky, while accepting the alternate route and avoiding the flooded area would be avoiding the risk.

The second dependent variable was the participants' trust in the navigation system. This was measured by the questions from Jian and colleagues (2000), which consisted of 12 statements that measure trust in a system (see Appendix D). In this scenario, the system was the mobile navigation application system. These statements were rated on a 7-point Likert scale, where 1 indicates that they strongly disagree with the statement, and 7 indicates that they strongly agree with the statement.

The third dependent variable was the participants' understanding of the warning. This variable measured their understanding of the warning and their comprehension of their given scenario. A total of 4 questions were used to measure their understanding (see Appendix B). Some of these questions had the same correct answer across the conditions while others varied depending on the scenario that they were presented with. For example, all scenario conditions stated that the participant was driving a Honda Civic sedan but the scenario conditions differed in the type of flood information given.

There were a few other measures in addition to the dependent variables. The post-experiment questions included demographic questions, questions that asked about the participants' primary mode of transportation, and the participants' current location's flood history, which measured how much exposure to floods they had in the location they currently

live in. Exposure to floods was on a 7-point Likert scale where the score of 1 means that it did not flood, while a score of 7 represents that it flooded a great deal. Three questions asked about previous driving experience, such as their age when they first received their driver's license, frequency of driving, and the number of miles driven in the past year. Two questions also asked about past flood history for if they had driven through a flooded roadway before and if they had ever gotten stuck. It was possible that if they had driven through flooded roadways in the past, but had never gotten stuck, then they may be more likely to drive through flooded roadways in the future. But then if they had driven through flooded roadways in the past and had gotten stuck, it was possible that they would be less likely to drive through flooded roadways in the future. Lastly, one question asked about their mobile navigation application experience.

CHAPTER 3

RESULTS

Participants who scored higher than 19 on the MSSQ (*n* = 9), who did not have normal or corrected-to-normal hearing and vision (*n* =2), or who had incomplete scenarios (*n* = 9) were excluded from the data analyses. Seventy-three valid participants were included in the data analyses. Of these 73 participants, the mean reported age was 19.95 years (*SD* = 4.03). Participants reported their gender as male (*n* = 24) or female (*n* = 49). Participants also reported their ethnicity as Caucasian, Non-Hispanic (*n* = 27), Black, Non-Hispanic (*n* = 25), Asian/Pacific Islander (*n* = 2), Hispanic (*n* = 9), or Other/Unknown (*n* = 10). Participants reported their highest level of education as high school graduate (high school diploma or equivalent including GED) (*n* = 24), some college but no degree (*n* = 46), or associate degree in college (2-year) (*n* = 3). The mean reported age participants first obtained their license was 16.59 years (*N* = 73, *SD* = 1.21). All of the following calculations and analyses were computed through IBM SPSS Statistics (Version 25), a statistical program.

3.1 Actions Taken

Hypotheses 1, 2, and 3 focused on the participants' actions concerning the flood warning. Their actions were binarily coded based on whether the participant chose to drive through the flooded roadway or not. Driving through the flooded roadway was coded as 1, while all the other options were coded as 0. For this coding method, 1 represents risky while 0 represents risk-avoidant. This coding method was used to compare the decisions that the participants chose to take in the different flood conditions. Since this DV was coded into a binary measure, it has less power than a continuous measure, and thus needed more participants, which was reflected in

G*Power (Version 3.1), a statistical power analysis program (Faul et al., 2009), using an alpha level of .05, a power level of .80, and the odds ratio from our prior research for logistic regression (Garcia et al., 2021; see Appendix F).

To test Hypotheses 1, 2, and 3, logistic regression analyses were conducted to properly model the categorical dependent variables rather than a factorial analysis of variance (ANOVA). A logistic regression was used to describe the data and explained the relationship between the binary dependent variable, whether participants kept the original route or not, and the independent variable of type of flood information, while controlling for past flood experience, perceived risk, and gender.

The additional questions from Kyriakidis and colleagues (2015) included two questions about past flood experience (see Appendix E). If participants reported that they had never driven through flooded roadways, then their score was coded as a 1; if they had rarely driven through flooded roadways, they were coded as 2; if they had driven through flooded roadways occasionally, they were coded as 3; if they had driven through flooded roadways sometimes, they were coded as 4; if they had driven through flooded roadways frequently, they were coded as 5; if they had driven through flooded roadways usually, they were coded as 6; and lastly, if they had always driven through flooded roadways every time, then they were coded as 7. Using this same scale, if they had never driven through a flooded roadway and had never gotten stuck in the floodwaters, then their score was multiplied by 1, and if they got stuck every time, then their score was multiplied by 7. A final score of 1 represents that they had never driven through flooded roadways (i.e., risk-avoidant), while a final score of 49 represents that they had driven through flooded roadways every time and got stuck every time (i.e., risk-taking). Their past flood

experience was used as a covariate in the analyses. The average past flood experience score was 2.56 (*N* = 73, *SD* = 1.54), where the minimum score was 1 and the maximum score was 8.

Perceived risk was scored on a scale of 1 to 12, where 1 represents no risk and 12 represents a great deal of risk. A final perceived risk score was computed by averaging the five questions on perceived risk and was used as a covariate in the analyses. Gender was categorically coded where 1 represents male and 2 represents female given the responses of the participants. Gender was also used as a covariate in the analyses.

A logistic regression was performed to examine the effects of flood information on action taken after the warning while including past flood experience, perceived risk, and gender as covariates to test Hypotheses 1 and 2. Hypothesis 1 claimed participants would keep the same route more often when the warning informs them that there is no flood expected on their route compared to when the warning informs them that there is a flooded roadway with no specific depth. Hypothesis 2 claimed participants would keep the same route more often when the warning informs them there is no flood expected compared to when the warning informs them that there is a flooded roadway with a specific depth. For this analysis, the flood conditions were dummy coded with the no-flood condition as the reference group. The responses in the no-flood condition were the baseline for the participants' original action given the warning in Waze. Thus, the actions of keeping the same route in the yes-flood and flood of 6 inches conditions, a risky decision, were compared to those who kept the same route in the no-flood condition, a protective decision (see Table 1).

Table 1

Effect of Flood Information on Percentage of Participants Displaying Risk-Avoidant Responses

Scenario	Percentage of Avoidant Responses (%)
Flood	97.3
No Flood	56.2
Flood of 6 inches	95.9
Flood of 6 inches Maximum	98.6

Note. $N = 73$.

Several assumptions for a logistic regression were met. The dependent variable of action taken after the warning was measured on a dichotomous scale as either a flood risk-avoidant response or as a flood risk-seeking response, had mutually exclusive and exhaustive categories, and had no extreme outliers, which were defined as any data value greater than three interquartile ranges than the third quartile, or lower than three interquartile ranges than the first quartile. The independent variable of flood information in the warning was a categorical variable. The sample size was sufficiently large based on the a priori power analysis. The sample was collected through voluntary response sampling by allowing participants to sign up for this study through SONA and each participant took part in the study individually, so the assumption of independence of observations was met. There was no multicollinearity among the predictors as found through small correlation coefficient magnitudes except between perceived risk and the quadratic perceived risk, $r(290) = .96$, $p < .001$. The assumption of linearity between a continuous covariate and the logit transformation of the dependent variable was not met for the perceived risk covariate as found by the Box-Tidwell procedure which tests for linearity, which is why the quadratic perceived risk was added to the model to capture the nonlinearity for that continuous variable in the model.

The logistic regression model was statistically significant, $\chi^2(7, N = 292) = 83.03$, $p < .001$. The full model explained 45.5% (Nagelkerke R^2) of the variance in action taken after the warning and correctly classified 88.4% of actions. The inverted odds ratio indicated that, when holding past flood experience, gender, and perceived risk constant, the odds of participants continuing straight for the no-flood condition (43.8%) was 7.52 times higher than the yes-flood condition (2.7%), 6.67 times higher than the flood of 6 inches condition (4.1%), and 22.22 times higher than the flood of 6 inches maximum condition (1.4%; all comparisons were statistically significant; see Table 2). The Box-Tidwell tested the assumption of a linear relationship between the continuous covariates and their logit transformation of the action taken after the warning. Perceived risk violated this assumption of linearity, thus a polynomial of the covariate was added to the model. Both the linear and quadratic components of perceived risk were significant predictors in the model. Increasing perceived risk was associated with more participants avoiding the possible flooded roadway. However, increasing perceived risk squared was associated with fewer participants avoiding the possible flooded roadway, a risk-seeking response. Neither past flood experience nor gender significantly predicted actions taken after the warning in the model. This analysis showed us that participants displayed more avoidant responses when given a general flood warning compared to a warning that there is no flood expected on their route (supporting Hypothesis 1), and that participants displayed more avoidant responses when given a flood warning with flood depth information compared to a warning that there is no flood expected on their route (supporting Hypothesis 2).

Table 2

Logistic Regression Predicting Action Taken from Flood Information, Past Flood Experience, Perceived Risk, and Gender for Hypotheses 1 and 2

Predictor	*B*	*SE*	Wald χ^2	*p*	Odds Ratio
Flood	-2.02	0.72	7.81	.005	.13
Flood of 6 in	-1.90	0.75	6.40	.011	.15
Flood of 6 in Max	-3.10	1.10	7.89	.005	.045
Past Flood Experience	0.22	0.14	2.60	.107	1.25
Gender	0.16	0.46	0.13	.720	1.18
Perceived Risk	-0.87	0.30	8.52	.004	0.42
$(\text{Perceived Risk})^2$	0.06	0.03	5.95	.015	1.06

Note. The no-flood condition was used as the reference group.

Another logistic regression was performed with the same model to find the effects of flood information on action taken after the warning while including past flood experience, perceived risk, and gender as covariates to test Hypothesis 3. This hypothesis claimed participants would display more flood avoidant actions when the warning informs them that there is a flood expected on their route with no specific depth compared to when the warning informs them that there is a flooded roadway with a specific depth. For this analysis, the flood conditions were dummy coded with the yes-flood condition as the reference group. The odds ratio and inverted odds ratio indicated that, when holding past flood experience, gender, and perceived risk constant, the odds of participants continuing straight and driving through a possible flood for the yes-flood condition (2.7%) was 1.12 times lower than the flood of 6 inches condition (4.1%), and 2.94 times higher than the flood of 6 inches maximum condition (1.4%; neither of these two comparisons were significant; see Table 3). This analysis showed us that participants did not display more avoidant responses when given a general flood warning

compared to a flood warning that included flood depth information (not supporting Hypothesis 3).

Table 3

Logistic Regression Predicting Action Taken from Flood Information, Past Flood Experience, Perceived Risk, and Gender for Hypothesis 3

Predictor	*B*	*SE*	Wald χ^2	*p*	Odds Ratio
No Flood	2.02	0.72	7.81	.005	7.50
Flood of 6 in	0.12	0.85	0.02	.892	1.12
Flood of 6 in Max	-1.08	1.18	0.84	.359	0.34
Past Flood Experience	0.22	0.14	2.60	.107	1.25
Gender	0.16	0.46	0.13	.720	1.18
Perceived Risk	-0.87	0.30	8.52	.004	0.42
$(\text{Perceived Risk})^2$	0.06	0.03	5.95	.015	1.06

Note. The yes-flood condition was used as the reference group.

3.2 Trust

Hypothesis 4 was an exploratory hypothesis that stated trust would increase as the level of detail increased in the flood warning. The trust questions adapted from Jian and colleagues (2000) consisted of 12 statements that measure trust in the navigation system on a 7-point Likert scale where 1 indicates they strongly disagreed with the statement, and 7 indicates that they strongly agreed with the statement (see Appendix D). Five of these statements were reverse coded so 1 represents no trust, and 7 represents trust. These trust questions were then compiled by averaging them into a single trust score.

The dependent variable trust was a continuous variable, had a normal distribution for the yes-flood condition (*Skewness* = -0.60, *Kurtosis* = 0.82), no-flood condition (*Skewness* = -0.70, *Kurtosis* = 0.51), flood of 6 inches condition (*Skewness* = 0.07, *Kurtosis* = -0.45), and flood of 6 inches maximum condition (*Skewness* = -0.47, *Kurtosis* = 0.13), and had no extreme outliers for any of the flood information conditions. Controlling for past flood experience, perceived risk, and gender, Mauchly's test of sphericity was not significant, indicating that the variances were homogeneous, $\chi^2(5) = 10.85$, $p = .055$. Since participants were recruited through voluntary response sampling, the assumption of independence of observations was met. The assumption of homogeneity of regression was not met since there was a significant interaction between the covariate perceived risk and the independent variable of flood information, $F(3, 198) = 3.35$, $p = .020$, $\eta_p^2 = .048$. The independence of treatment and covariate assumption was also not met since the covariate perceived risk was related to the independent variable of flood information, $F(3, 288) = 42.54$, $p < .001$, $\eta_p^2 = .307$.

An analysis of covariance (ANCOVA) was conducted with the trust scores based on the flood information, controlling for past actions of driving through flooded roadways, perceived risk, and gender. This analysis revealed that after controlling for past flood experience, perceived risk, and gender, there was no significant difference in trust between the flood information conditions, $F(3, 198) = 0.17$, $p = .917$, $\eta_p^2 = .003$. There was no difference in the levels of granularity for the warnings in the context of trust while controlling for past flood experience, perceived risk, and gender (not supporting Hypothesis 4; see Table 4). There was a significant interaction between trust and the covariate perceived risk for the flood of 6 inches maximum scenario, $F(3, 198) = 3.35$, $p = .020$, $\eta_p^2 = .048$. Perceived risk for the flood of 6 inches maximum scenario was a significant predictor of trust in the navigations system; trust depended

on perceived risk in the flood of 6 inches maximum scenario, consistent with Mayer and colleagues' model of trust (1995) which found perceived risk to be a significant predictor of trust. No other interactions between trust and covariates were significant, *p*s > .050.

Table 4

Means for Trust by Flood Information

Source	*n*	*Raw Mean*	*SE*	*Adjusted Mean*	*SE*
Trust for Flood	73	5.64	0.10	5.64	0.10
Trust for No Flood	73	5.50	0.11	5.51	0.11
Trust for Flood of 6 in	73	5.68	0.08	5.68	0.08
Trust for Flood of 6 in Max	73	5.62	0.10	5.62	0.10

Note. Adjusted means in the model were evaluated at: perceived risk in flood = 6.51, perceived risk in no flood = 2.57, perceived risk in flood of 6 inches = 6.84, perceived risk in flood of 6 inches maximum = 6.76, gender = 1.67, and past flood experience = 2.56.

3.3 Understanding

The questions that measured the participants' understanding of the warning and their comprehension of their given scenario (see Appendix B) were compiled by averaging them to create a single Understanding score for each participant. If they got the answer correct, then the score for that question was coded as 1, while if they answered incorrectly, that question was coded as 0. For questions 1 and 2 asking about where they opened their GPS and the type of car driven, the correct answers were, "in the car," and "sedan (Honda Civic)," respectively. These answers were correct regardless of the scenario condition. For question 3 asking about the nature

of the flood situation, the correct answer was, “there was a flood (with no specific depth) expected on my route,” “there was no flood expected on my route,” “there was a flood of 6 inches expected on my route,” or “there was a flood of 6 inches maximum expected on my route” depending on if the participant was in the yes-flood, no-flood, flood of 6 inches, or flood of 6 inches maximum condition, respectively. Lastly for question 4 asking about the depth of the flood, if they were in the no-flood condition, then the correct answer was “0.” If they were in the flood of 6 inches condition, then the correct answer was “6.” If they were in the flood of 6 inches maximum condition, then the correct answer was any number from zero to six. If they were in the yes-flood condition, then any number greater than zero was correct and acceptable. This information also provided details to what drivers believed the depth of the flood was when no depth information was presented and how they acted based on their beliefs.

A point-biserial correlation was used to measure the linear relationship between the Understanding score, a continuous variable, and the actions taken, if the participant kept the original route or not, a dichotomous variable. There were no extreme outliers in any of the Understanding scores except in the no-flood condition where there were six. All the Understanding scores were negatively skewed and leptokurtic except for in the flood of 6 inches maximum condition (flood: *Skewness* = -1.39, *Kurtosis* = 1.55; no flood: *Skewness* = -4.02, *Kurtosis* = 19.19; flood of 6 inches: *Skewness* = -1.95, *Kurtosis* = 3.56; flood of 6 inches maximum: *Skewness* = -1.13, *Kurtosis* = 0.09). Levene’s test of equality of variances was significant, meaning that the Understanding score had unequal variances for each category of actions taken, $F(1, 290) = 12.28$, $p < .001$. The point-biserial correlation was not significant, $r(290) = .112$, $p = .056$. There was no significant linear relationship between the Understanding score and actions taken.

Since there were six extreme outliers in the no-flood condition, the analysis was rerun with the outliers removed and showed similar results. The Understanding score for the no-flood condition was still negatively skewed and leptokurtic (*Skewness* = -5.65, *Kurtosis* = 30.88). Levene's test was still significant, $F(1, 284) = 13.34$, $p < .001$. The point-biserial correlation was also still not significant, $r(284) = .115$, $p = .052$. Even with removing the extreme outliers, there was not a significant linear relationship between the Understanding score and actions taken.

Participants reported their estimated depth for the flood water in each flood scenario. The mean depth for the yes-flood condition was 4.33 inches (*SE* = 0.22), where the maximum reported depth was 8 inches and the minimum was 0 inches (*n* = 60). The mean depth for the no-flood condition was 0.05 inches (*SE* = 0.05), where the maximum reported depth was 3 inches and the minimum was 0 inches (*n* = 66). The mean depth for the flood of 6 inches condition was 5.56 inches (*SE* = 0.12), where the maximum reported depth was 6 inches and the minimum was 1 inch (*n* = 71). Lastly, the mean depth for the flood of 6 inches maximum condition was 5.99 inches (*SE* = 0.21), where the maximum reported depth was 20 inches and the minimum was 3 inches (*n* = 71).

3.4 Perceived Risk

Perceived risk was used as a covariate in the logistic regression analyses to test Hypothesis 1, 2, and 3, as well as in the ANCOVA to test Hypothesis 4. These analyses indicated that perceived risk was closely related to the independent variable of flood information. A post-hoc repeated measures ANCOVA was conducted on perceived risk to determine if flood information had an effect on perceived risk while controlling for past flood experience and gender.

The dependent variable of perceived risk was a continuous variable. The independent variable of flood information had at least two categorical groups. Perceived risk had a normal distribution for the yes-flood condition (*Skewness* = 0.01, *Kurtosis* = -0.97), but a positively skewed and leptokurtic distribution for the no-flood condition (*Skewness* = 2.03, *Kurtosis* = 4.41), and a platykurtic distribution for the flood of 6 inches condition (*Skewness* = -0.11, *Kurtosis* = -1.12) and flood of 6 inches maximum condition (*Skewness* = -0.06, *Kurtosis* = -1.07). There were only two extreme outliers of perceived risk in the no-flood condition. Controlling for past flood experience and gender, Mauchly's test of sphericity was significant, indicating that the variances were not homogeneous, $\chi^2(5) = 65.71$, $p < .001$. The assumption of homogeneity of regression was met since there were no significant interactions between the covariate past flood experience and the independent variable of flood information, $F(3, 210) = 0.94$, $p = .424$, $\eta_p^2 = .013$, nor between gender and flood information, $F(3, 210) = 0.83$, $p = .480$, $\eta_p^2 = .012$. The independence of treatment and covariate assumption was also met since the covariates past flood experience and gender were not related to the independent variable of flood information. Voluntary response sampling was used to recruit participants and the assumption of independence of observations was met.

Using the Greenhouse-Geisser adjustment, the ANCOVA revealed that after controlling for past flood experience and gender, there was a significant difference in perceived risk scores between flood information conditions, $F(1.97, 137.52) = 4.23$, $p = .017$, $\eta_p^2 = .057$. Controlling for past flood experience and gender, perceived risk scores were significantly lower in the no-flood condition (*Adj. M* = 2.57, *Adj. SE* = 0.27) than in the yes-flood condition (*Adj. M* = 6.51, *Adj. SE* = 0.34), flood of 6 inches condition (*Adj. M* = 6.84, *Adj. SE* = 0.31), and flood of 6 inches maximum condition (*Adj. M* = 6.76, *Adj. SE* = 0.32; *p*s < .001 for all three comparisons;

see Table 5). Neither interaction between perceived risk and gender, nor past flood experience, were significant, *F*s < 1.

Table 5

Means for Perceived Risk by Flood Information with Outliers

Source	*n*	*Raw Mean*	*SE*	*Adjusted Mean*	*SE*
Risk for Flood	73	6.51	0.34	6.51	0.34
Risk for No Flood	73	2.57	0.27	2.57	0.27
Risk for Flood of 6 in	73	6.84	0.32	6.84	0.31
Risk for Flood of 6 in Max	73	6.76	0.33	6.76	0.32

Note. Adjusted means in the model were evaluated at: gender = 1.67, and past flood experience = 2.56.

Since there were two extreme outliers in the no-flood condition, they were removed and the analysis was rerun and showed similar results. The no-flood condition still had a positively skewed and leptokurtic distribution (*Skewness* = 1.57, *Kurtosis* = 1.94). Controlling for past flood experience and gender, Mauchly's test of sphericity was still significant, $\chi^2(5) = 51.94$, $p < .001$. The assumption of homogeneity of regression was met again since there were no significant interactions between the covariate past flood experience and the independent variable of flood information, $F(3, 204) = 1.67$, $p = .175$, $\eta_p^2 = .024$, nor between gender and flood information, $F(3, 204) = 0.55$, $p = .650$, $\eta_p^2 = .008$. The independence of treatment and covariate assumption was also met again since the covariates past flood experience and gender were not related to the independent variable of flood information.

Using the Greenhouse-Geisser adjustment, the ANCOVA revealed that after controlling for past flood experience and gender and removing the two extreme outliers, there was still a significant difference in perceived risk scores between flood information conditions, $F(2.12, 144.37) = 8.48$, $p < .001$, $\eta_p^2 = .111$. Controlling for past flood experience and gender, perceived risk scores were still significantly lower in the no-flood condition (*Adj. M* = 2.33, *Adj. SE* = 0.22) than in the yes-flood condition (*Adj. M* = 6.49, *Adj. SE* = 0.35), flood of 6 inches condition (*Adj. M* = 6.82, *Adj. SE* = 0.32), and flood of 6 inches maximum condition (*Adj. M* = 6.74, *Adj. SE* = 0.33; *p*s < .001 for all three comparisons; see Table 6). Neither interaction between perceived risk and gender, nor past flood experience, were significant, *p*s > .050.

Table 6

Means for Perceived Risk by Flood Information without Outliers

Source	*n*	*Raw Mean*	*SE*	*Adjusted Mean*	*SE*
Risk for Flood	71	6.49	0.35	6.49	0.35
Risk for No Flood	71	2.33	0.22	2.33	0.22
Risk for Flood of 6 in	71	6.82	0.33	6.82	0.32
Risk for Flood of 6 in Max	71	6.74	0.33	6.74	0.33

Note. Adjusted means in the model were evaluated at: gender = 1.69, and past flood experience = 2.59.

3.5 Vehicle Kinematics

In addition to the measures collected from the questionnaires, vehicle kinematic data were collected from the driving simulator. The STISIM driving simulator collected data such as

longitudinal and lateral distance, velocity, and acceleration of the vehicle on the road, speedometer value, acceleration from the gas and brake pedals, and steering wheel angle. These measures were organized based on time and were collected every 0.03 seconds. Since all the flood scenarios had the participants drive straight until the flood warning, the data collected starting from the onset of the flood warning were investigated for each flood information type.

The data were first cleaned by setting the time, longitudinal distance, acceleration from gas and brake pedals, and steering wheel angle for each participant to zero at the start of the warning in each flood scenario. Because the STISIM recorded the data based on time, and each driver drove at a different speed, everyone had a different initial time and acceleration at the start of the warning. Participants also had a different longitudinal distance because each flood scenario had a different total distance for the vehicle to travel. By standardizing the time and longitudinal distance to zero, comparisons were able to be made between participants and flood simulations.

For all four scenarios, the flood warning was set to occur 550 feet before the start of the intersection and remained on the screen for 200 feet. The alternate route alert was set to occur 350 feet before the start of the intersection and remained on the screen for 350 feet. Assuming the driver maintained the posted speed limit of 30 miles per hour (mph), they would have at least 9.97 seconds after the complete auditory flood warning, and 2.95 seconds after the complete auditory alternate route warning before the start of the intersection. Because the distance from the start of the flood warnings was the same for each flood scenario, the data among flood scenarios could be compared.

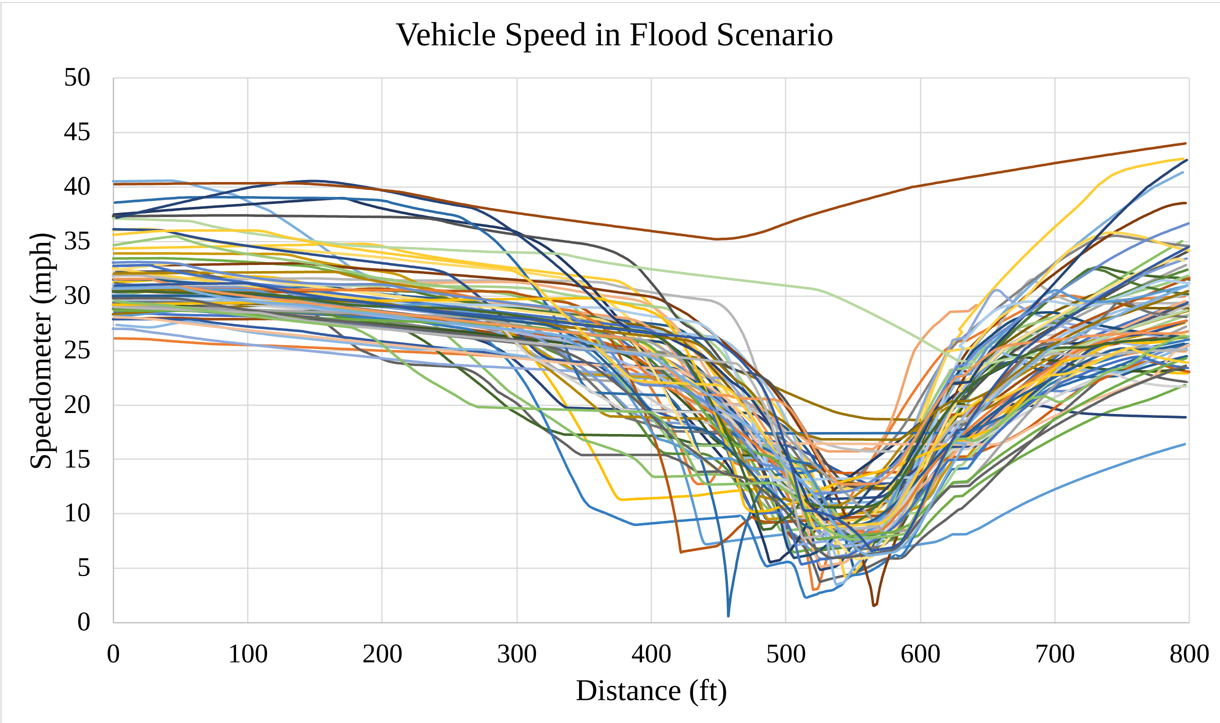
The STISIM program utilizes partial virtual environment generation, which means that only a portion of the virtual world is displayed as the driver goes down the road (Systems

Technology Inc., n.d.). For intersections, no matter which forward direction or turn the driver takes, the same event, buildings, and objects will be displayed; however, there may be a lag in object appearance during a turn, which was advantageously used for the flood scenarios. In the flood scenarios, there was a lag in the collected longitudinal distance when drivers turned at the intersection, however, the lateral distance continued to increase. The lateral distance measured the vehicle's lane position with respect to the roadway dividing line, where positive values are to the right of the line. This lag was supplemented by computing a summed distance of zeroed longitudinal distance and the absolute value of lateral distance, subtracting the starting lateral lane position.

The summed distance was used to graph the changes in speed by the vehicle in each scenario from the onset of the flood warning as they approached the intersection and their decision regarding it (see Figure 9). In Figure 9, the variations of speed for each individual in each scenario can be seen. In the no-flood scenario, 32 drivers decided to continue straight compared to two drivers in the flood scenario, three drivers in the flood of 6 inches scenario, and one driver in the flood of 6 inches maximum (see Table 1 and Figure 9). All participants' speed data by distance were organized into two categories depending on their turning decisions and averaged with each other for each flood scenario (see Figure 10). In Figure 10, the speed trends for all the individuals can be compared based on the scenario and their turning decision.

Figure 9

Speed Over Distance by Driver and Scenario



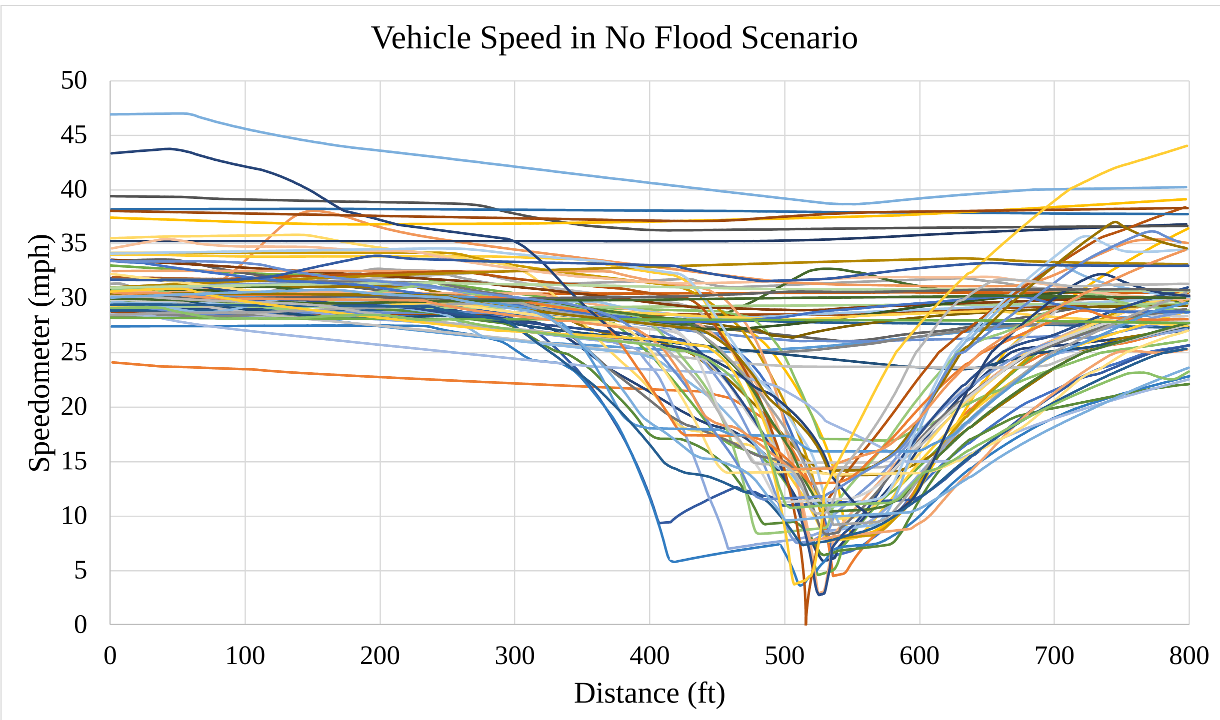
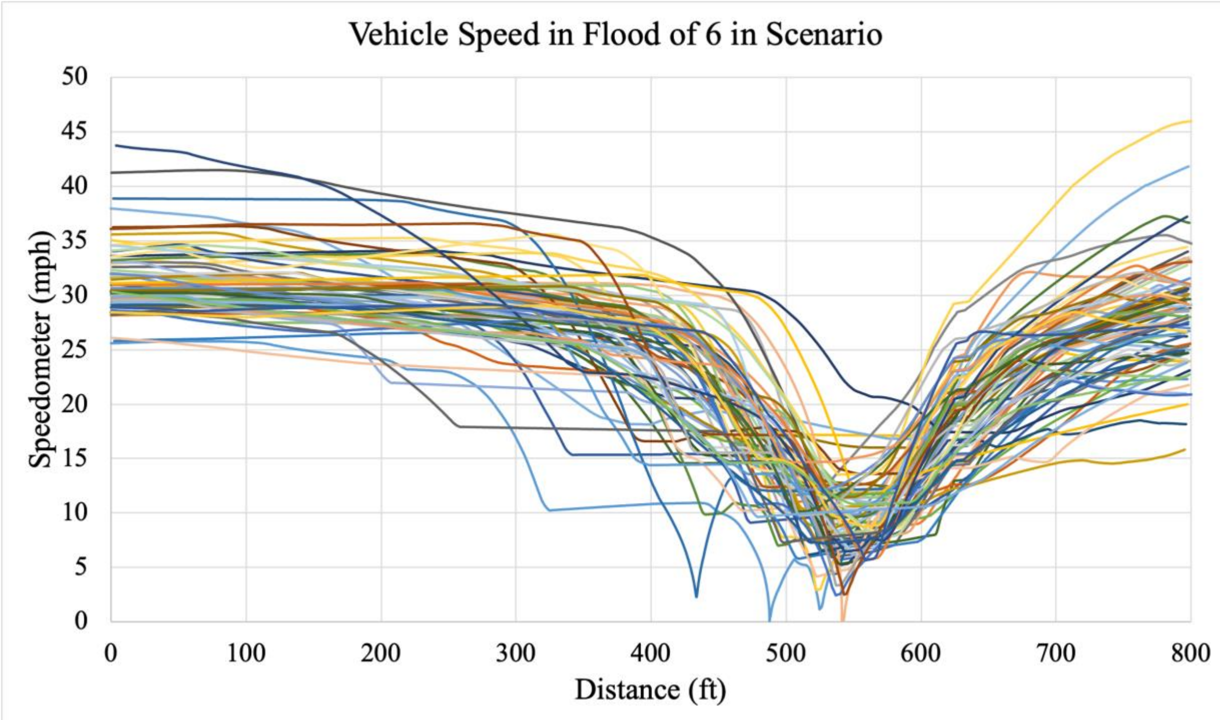
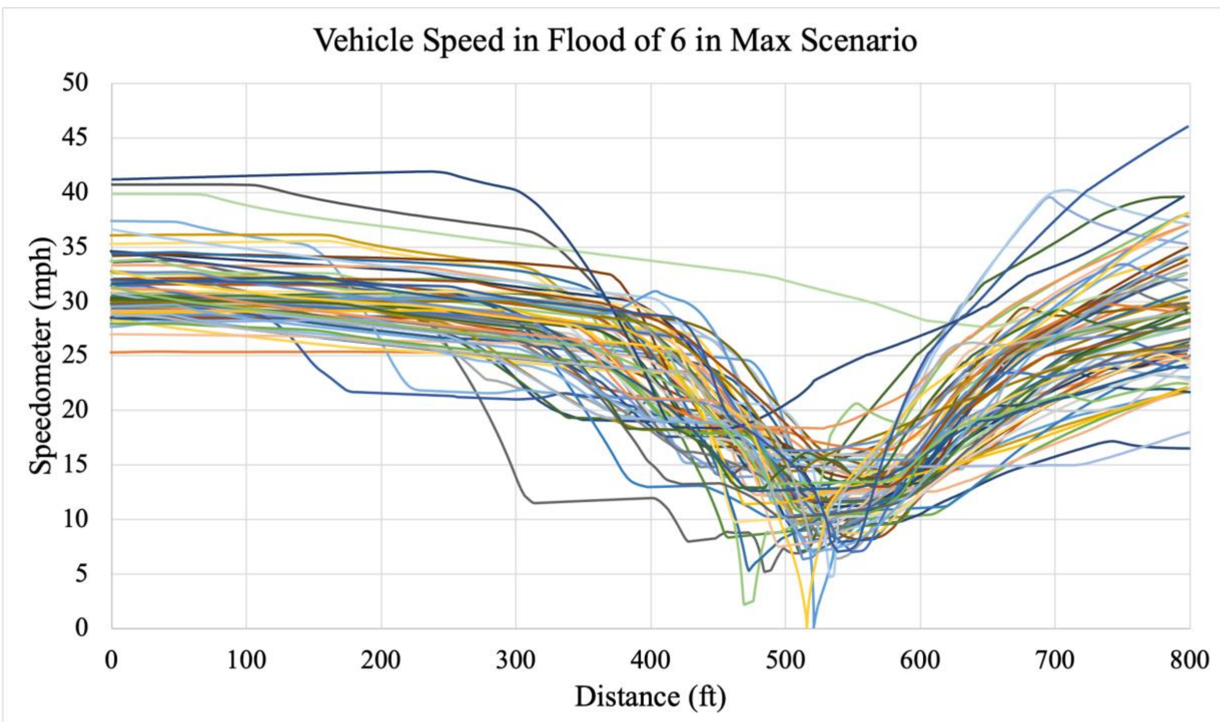


Figure 9 Continued

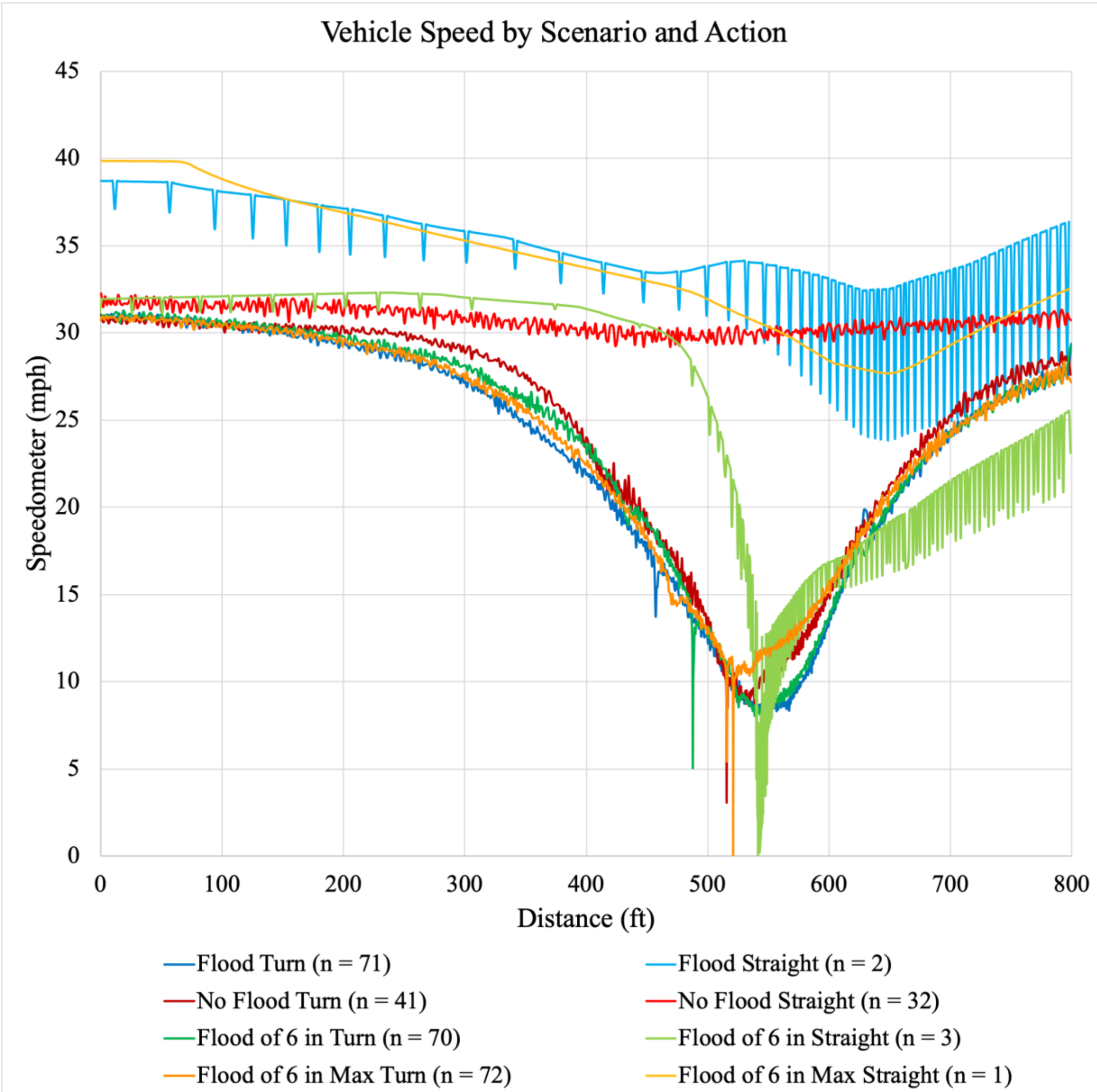




Note. N = 73 for each flood scenario.

Figure 10

Speed Over Distance All Scenarios



Note. Participant speed data by distance were averaged based on turn decision.

Acceleration of the vehicle based on the drivers' gas and brake pedal inputs was also collected. These data were used to analyze the drivers' response time to the onset of the warning for each scenario. A change in pedal depression that caused an acceleration or deceleration of more than 1 meter per second squared (m/s^2), or 2.24 mph, counted as a response (see Hergeth et al., 2017; Radlmayr et al., 2014). In addition to the pedal inputs, the steering wheel angle was also collected to assess response time to the warning. A response time from the steering wheel was counted when there was a change in angle of at least two degrees (see Hergeth et al., 2017; Radlmayr et al., 2014; Merat et al., 2012). Based on these criteria, the response times from the gas pedal, brake pedal, and steering wheel inputs were recorded.

The dependent variable of response time was the fastest response from either the gas pedal, brake pedal, or steering wheel input in each scenario for each participant and was a continuous variable. The assumption of independence of observation was met since participants were recruited through voluntary response sampling. The independent variable was the flood information, which had four categorical groups. The response times for those in the flood (*Skewness* = 0.02, *Kurtosis* = 0.32), no flood (*Skewness* = -0.53, *Kurtosis* = 0.38), flood of 6 inches (*Skewness* = -0.59, *Kurtosis* = -0.77), and flood of 6 inches maximum (*Skewness* = -0.38, *Kurtosis* = -0.58) conditions were all normally distributed. There were no extreme outliers in any of the flood information conditions. Mauchly's test of sphericity was not significant for the response times, indicating that the variances were homogeneous, $\chi^2(5) = 9.07$, $p = .106$.

The repeated-measures one-way ANOVA revealed that there was a significant difference in response time to the onset of the flood warning between flood information conditions, $F(3, 147) = 4.04$, $p = .009$, $\eta_p^2 = .076$. The response times were significantly faster in the flood of 6 inches maximum condition (*M* = 6.79, *SE* = 0.44) than in the no-flood condition (*M* = 7.85, *SE* =

0.49; $p = .007$; see Table 7). There were no other significant pairwise comparisons between the flood information conditions, *p*s > .050.

Table 7

Means for Response Times by Flood Information

Source	*n*	*Mean*	*SE*
Response Time for Flood	50	6.54	0.50
Response Time for No Flood	50	7.85	0.49
Response Time for Flood of 6 in	50	6.79	0.48
Response Time for Flood of 6 in Max	50	6.06	0.44

Note. Response time is in seconds and was the fastest time from either the gas pedal, brake pedal, or steering wheel input for each participant.

CHAPTER 4

DISCUSSION

This thesis investigated flood warning information, past flood experience, perceived risk, and gender as factors that affect drivers' understanding and turning decisions when given a flood warning through their mobile device in a driving simulator scenario. Flood warnings alert the public of the risk of potential floods. In the context of driving, flood warnings can be communicated through mobile devices to keep drivers and passengers safe from flooded areas. Flood warnings can vary in the level of detail conveyed to the driver about the potential flood. In this study, participants experienced four different flood scenarios with varying levels of warning details and had to decide if they would continue straight on their route, a risky decision, or accept the navigation system's suggestion of an alternate route, a risk-averse decision. After each scenario, participants rated their trust in the navigation system, understanding, and perceived risk of the flood scenario.

4.1 Actions Taken

Hypothesis 1 expected participants to continue straight more often in the no-flood condition than in the flood condition based on pilot results (Garcia et al., 2021) and because continuing straight in the no-flood condition is considered a risk-averse decision since there is no flood expected. Results showed that participants decided to continue straight more often in the no-flood scenario (43.8%) than in the flood scenario (2.7%) while controlling for past flood experience, perceived risk, and gender, supporting Hypothesis 1 (see Table 1). This result supports the pilot results (Garcia et al., 2021) and shows that participants were more risk-averse than risk-seeking for this decision since they turned more often in the flood condition, where the

alternative of continuing straight through the flood is a risky decision, than in the no-flood condition. One participant in the flood scenario turned the opposite way, turning left instead of right as advised by the navigation system. This action was still considered risk-avoidant since they did not drive through the flood, even though they did not accept the advice from the navigation system.

Hypothesis 2 expected participants to continue straight more often in the no-flood condition than in the flood of 6 inches condition and in the flood of 6 inches maximum condition based on pilot results (Garcia et al., 2021), and similar rationale to that of Hypothesis 1. Results showed participants continued straight more often in the no-flood scenario (43.8%) than in the flood of 6 inches (4.1%) and flood of 6 inches maximum (1.4%) scenarios while controlling for past flood experience, perceived risk, and gender, supporting Hypothesis 2 (see Table 1). This result again supports the pilot results (Garcia et al., 2021), and shows that participants were more risk-averse than risk-seeking in these scenarios since they turned more often to avoid the flood.

Hypothesis 3 expected participants to continue straight more often in the flood of 6 inches and flood of 6 inches maximum scenarios than in the general flood scenario based on pilot results (Garcia et al., 2021). Results showed participants continued straight more often in the general flood scenario (2.7%) than in the flood of 6 inches maximum scenario (1.4%), but not than in the flood of 6 inches scenario (4.1%), while controlling for past flood experience, perceived risk, and gender, not supporting Hypothesis 3 (see Table 1). Because neither comparison was statistically significant, this result does not support the pilot results (Garcia et al., 2021); participants were almost equally risk-avoidant among these three scenarios.

In the no-flood condition, both decisions of continuing straight and turning were considered risk-averse since there was no flood expected and thus no danger of continuing

straight, unlike the other flood information conditions. The decisions of continuing straight (43.8%) and turning (56.2%) were almost equal, reflecting that participants considered both decisions to be similar in nature. This slight difference, where the majority of participants chose to accept the navigation system's alternate route and turn, may be due to wanting to follow the system's advice (Leshed et al., 2008). All of the participants (100%) had used a navigation system prior to this study and may be accustomed to following its directions (Leshed et al., 2008).

Another possibility is that it takes more effort and mental workload to make a decision regarding the route rather than following provided directions (Recarte & Nunes, 2003; Svenson, 1979; Van Winsum et al., 1989). It is possible that people prefer or are accustomed to blindly following the system's directions, which can lead to dangerous situations (Hansen, 2015; Leshed et al., 2008; Johnson et al., 2008). This possibility is also tied to location familiarity. It is possible that drivers rely more on the navigation system in unfamiliar areas than in familiar areas that they drive every day, such as from home to work (Leshed et al., 2008). Since the drivers were new and unfamiliar with the driving location in the simulations, they may have relied more on the navigation system than their own spatial navigation skills since they did not have a mental map of the area.

Both Hypotheses 1 and 2 were supported, showing that the participants were more risk-avoidant than risk-seeking since they avoided the flood by turning instead of driving through it compared to the no-flood scenario. These hypotheses tested the responses to the warning content between a flood of any type and no flood rather than the detail of the warning. However, Hypothesis 3 was not supported, showing that the level of detail of the warning did not seem to influence the drivers' decisions as much as expected based on pilot results (Garcia et al., 2021).

The responses in the scenarios with a flood present were all very similar to each other. The warning with the most detail, the flood of 6 inches maximum, had the highest rate of avoidant responses, followed by the abstract general flood, and then the detailed flood of 6 inches.

It is also unlikely that the participants' responses were based on the content of the warning, the assumed depth of the flood. For the flood of 6 inches maximum warning, the depth of the flood can be anywhere from 1 to 6 inches, where participants averaged the depth to be 5.99 inches. Then the general flood warning has the most abstract depth interpretation since no depth information was given and can be anywhere from 1 to 20 inches, but participants, on average, estimated the flood in the general flood scenario to have a depth of 4.33 inches. For the flood of 6 inches warning, the depth of the flood is 6 inches, however, participants estimated it to be 5.56 inches. Even though the flood of 6 inches maximum warning contains more details, it leaves more room for interpretation since it provides a range for the flood compared to the flood of 6 inches warning. However, the average estimated depth was 5.99 inches, compared to the flood in the flood of 6 inches scenario which was estimated at 5.56 inches and had the least room for interpretation. Then the general flood warning had the lowest level of detail yet had the largest range of flood depth possibilities. This, again, shows that the level of detail of the warning does not seem to influence the drivers' decision, and neither does the interpreted depth of the flood (see Table 8).

Table 8

Expected Results from Hypotheses and Actual Results for Avoidant Responses and Assumed Depth Ranked

	Hypothesized Results			Results	
	Hypothesis 1	Hypothesis 2	Hypothesis 3	Avoidant Responses (%)	Assumed Depth (inches)
Most Risk-Avoidant	Flood	Flood of 6 in and Flood of 6 in Max	Flood of 6 in Max	Flood of 6 in Max (98.6%)	Flood of 6 in Max (5.99)
			Flood of 6 in	Flood (97.3%)	Flood of 6 in (5.56)
			Flood	Flood of 6 in (95.9%)	Flood (4.33)
Least Risk-Avoidant	No Flood	No Flood		No Flood (56.2%)	No Flood (0.05)

Note. For the hypotheses' columns, it is from greatest avoidant responses to least avoidant responses for the flood conditions involved.

For those that drove through the flood, it is possible that they overestimated their vehicle's ability to drive through the flood since the depth of the flood was provided, which is especially common for the age group of 20-29, where the average age of participants was 19.95 (Han & Sharif, 2020). Drivers may believe that the deeper the flood, the more dangerous it is, although any flood of 4 inches or more can reach the bottom of a sedan vehicle and cause a chain reaction to damage the engine (C., 2021; Gerhardt, 2019). This leads to the idea that drivers do not fully understand the capabilities of their vehicle regarding crossing flooded roadways, where a few inches make a big difference. It is also possible that the drivers disregarded the flood warning and based their decision on the observed flood ahead of them. However, the look of the

flood was the same between the scenarios that contained a flood and it is difficult to tell the depth of a real flood while driving (Xia et al., 2011). Another possibility is that the drivers were highly motivated to reach their destination and used this reasoning to drive through the flood (Hamilton et al., 2016).

For Hypotheses 1, 2, and 3, past flood experience and gender did not significantly predict the participants' turning decision based on the flood scenario, but perceived risk and the quadratic of perceived risk did. Increasing perceived risk was related to more risk-avoidant decisions, such as accepting the alternate route and turning. This is rational because the larger the risk seems, the more drivers would want to avoid it (Fiet, 2022). However, increasing perceived risk squared was related to more risk-seeking decisions, such as continuing straight through the flood. This may mean that the larger the risk, the more people would want to experience it and take the risk. This may be related to thrill-seeking experiences, such as skydiving and bungee jumping (Self et al., 2007). For some risks, up to a certain point, people may prefer to avoid them (Kimball, 1993; Dror et al., 1999). But then once the risk grows exponentially, certain people may prefer to take them for the thrilling experience (Self et al., 2007). This risk-seeking behavior is a characteristic of the personality type T (Self et al., 2007; Farley, 1991). It is also possible that the drivers who drove through the flood underestimated the risk of the flood conveyed by the warning (Morss et al., 2016).

It was interesting that gender and past flood experience did not significantly predict the participants' responses. This thesis adds to the literature on the effects of gender and previous flood experience. Both gender and past flood experience have mixed results regarding their relationship with driving through flooded roadways. Typically, men are riskier drivers than women by being more aggressive drivers (Berkowitz, 1993), driving faster with greater speed

variance (Lansdown, 2002), and being involved in more serious accidents (Storie, 1977). Previous studies found men to drive through flooded roadways more often than women (Drobot et al., 2007). However, other studies found no difference in gender for driving through a flooded roadway (Coles & Hirschboeck, 2020) making it unclear as to if there is an effect of gender or not. The result from this study found no difference between men and women for driving through a flooded roadway (Coles & Hirschboeck, 2020) and adds to the literature on the effects of gender on actions, leaning the literature in favor of gender not having an effect on flood crossing actions. Previous flood experience literature is mixed in favor that previous experiences do have an influence on actions regarding a flooded roadway and future risk perception (Pearson & Hamilton, 2014; Wachinger et al., 2013; Kellens et al., 2011; Burningham et al., 2008; Mol et al., 2022). However, this study demonstrated that past flood experience had no effect on if participants displayed avoidant responses given a flooded roadway, adding to the mixed literature against the effect of past flood experience (Drobot et al., 2007).

4.2 Trust

Hypothesis 4 was an exploratory hypothesis and expected participants to have more trust as the level of detail of the warning increased. Results showed that there was no difference in trust ratings in the navigation system between the flood information conditions while controlling for past flood experience, perceived risk, and gender, not supporting Hypothesis 4. There was a slight increase in trust ratings from the abstract level of detail (flood: *Adj. M* = 5.64; no flood: *Adj. M* = 5.51) to the higher level of detail containing the depth information (flood of 6 inches: *Adj. M* = 5.68; flood of 6 inches maximum: *Adj. M* = 5.62), but the difference was not significant (see Table 4). Past flood experience and gender did not predict trust, but perceived risk in the flood of 6 inches maximum scenario did.

Trust stayed consistently high for the navigation system, regardless of the detail of flood warning information presented. Trust scores were on a scale of 1 to 7, where 1 represents no trust and 7 represents complete trust. This can be tied back to why participants in the no-flood scenario chose to accept the alternate route more often than continue straight, even though both decisions were considered to be risk-avoidant. The participants may have trusted the navigation system to provide a viable alternate route for them, which influenced their decision regarding the flooded roadway (Coles & Hirschboeck, 2020).

Perceived risk predicted trust, but only the perceived risk in the flood of 6 inches maximum scenario. This result supports previous findings that risk is a significant predictor of trust (Mayer et al., 1995). The trust in the navigation system depended on the perceived risk for the flood of 6 inches maximum scenario. It is possible that it only depended on this one scenario because it contained the most detail out of the four flood information conditions, even though it did not have the highest trust score or perceived risk score among the conditions.

4.3 Understanding

The participants' understanding of the scenario and warning were analyzed to see if there was a linear relationship between their Understanding score and their actions taken. Results showed that there was no significant linear relationship between the participants' understanding of the warning and scenario and their turning decision. This result suggests that understanding the warning or situation does not relate to whether the driver will follow the navigation system's advice or not. It could be justified that drivers who did not understand the situation well chose to follow the navigation system's advice and avoid the flood because they trusted it and believed it was the best option (Hansen, 2015; Leshed et al., 2008; Johnson et al., 2008). Alternatively, it is possible that those who did not understand the situation well instead relied on their own

navigation skills and previous knowledge and experiences to drive through the flooded roadway, depending on their navigational skills (Leshed et al., 2008).

Participants also reported their estimated depth for the flood in each flood information condition. In the general flood scenario, which did not provide any depth information, participants averaged the depth to be 4.33 inches, which is substantially less than what was expected. In the second pilot study, participants estimated the depth of the flood to be 6 inches, however, participants estimated the depth on a scale of 0 to 12, where 6 is the median between the two values (Garcia et al., 2022). In the present study, participants were able to freely respond by entering a number into a blank box without any restrictions.

In the no-flood scenario, participants estimated the depth to be 0.05 inches on average, where the maximum reported depth was 3 inches. Only one participant reported the flood depth to be greater than 0 inches and reported it to be 3 inches in depth. The remaining participants accurately estimated the depth of the flood, which should be at 0 inches since there was no flood on their route, and thus does not have a depth.

In the flood of 6 inches condition, the average reported depth was 5.56 inches. For this scenario, it contained the detailed depth information, and was straightforward, meaning the depth is 6 inches. However, 14 participants reported the depth was less than 6 inches, where the minimum was 1 inch while 57 participants reported it to be at 6 inches. Participants may have interpreted the warning of 6 inches that it was around 6 inches rather than a direct given amount.

Lastly, in the flood of 6 inches maximum scenario, the reported average depth was 5.99 inches, which was more than the flood of 6 inches scenario. Seven participants reported the depth to be between 3 and 5 inches, one participant reported it to be 20 inches, and the other participants reported it to be 6 inches (n = 63). Even though the flood of 6 inches maximum

warning gave a range of options, more participants reported the depth to be 6 inches in this scenario than in the flood of 6 inches scenario, where the warning is more direct and does not provide a range. It is possible that participants believed the flood of 6 inches maximum warning conveyed that the flood was 6 inches more often than the flood of 6 inches warning.

4.4 Perceived Risk

Since perceived risk was closely related to the variable of flood information as seen through Hypotheses 1, 2, and 3, it was analyzed to see if there was a difference in perceived risk between the four flood scenarios. Results indicated that the perceived risk scores were significantly lower in the no-flood condition (*Adj. M* = 2.33) than in the flood (*Adj. M* = 6.49), flood of 6 inches (*Adj. M* = 6.82), and flood of 6 inches maximum (*Adj. M* = 6.74) conditions while controlling for past flood experience and gender. Neither gender nor past flood experience were significant predictors of perceived risk.

This result was expected since there is no risk associated with the no-flood scenario since either choice is considered risk-avoidant. These results are similar to the actions taken after the warning since participants avoided the flood significantly more in the scenarios where a flood was present compared to the no-flood scenario. This makes sense since perceived risk was a predictor of the action taken. These results also mimic the estimated flood depths reported by participants. The highest reported flood depth was for the flood of 6 inches maximum scenario at 5.99 inches, followed by the flood of 6 inches scenario at 5.56 inches, then by the flood scenario at 4.33 inches, then lastly by the no-flood scenario at 0.05 inches. The perceived risk increases as the estimated depth of the flood increases. As the depth of the flood water increases, the more damage it can do to the vehicle, which raises the risk of driving through the flooded roadway (Gerhardt, 2019; see Table 9).

Table 9

Perceived Risk, Avoidant Response and Assumed Depth Results Ranked

Perceived Risk (score)	Avoidant Responses (%)	Assumed Depth (inches)
Flood of 6 in (6.82)	Flood of 6 in Max (98.6%)	Flood of 6 in Max (5.99)
Flood of 6 in Max (6.74)	Flood (97.3%)	Flood of 6 in (5.56)
Flood (6.49)	Flood of 6 in (95.9%)	Flood (4.33)
No Flood (2.33)	No Flood (56.2%)	No Flood (0.05)

Note. Rows are ranked from most risky, most avoidant, and greatest depth, to least risky, least avoidant, and smallest depth from top to bottom.

Neither gender nor past flood experience predicted perceived risk. Both have had mixed findings in the past regarding their relationship with perceived risk. It has been found that women have a higher perceived level of flood risk than men (Kellens et al., 2011), but the result from the current study supports other studies that found no difference between men and women on perceived risk (Burningham et al., 2008; Mol et al., 2022). It was surprising that past flood experience did not predict perceived risk since a number of studies found an influence of past flood experience on perceived risk (Wachinger et al., 2013; Kellens et al., 2011; Burningham et al., 2008; Mol et al., 2022). This result may be due to the participants having minimal past flood experience since the average flood experience score was 2.56 out of a range of 1 to 49. Most participants rarely drove through flooded roadways (n = 25) and had never gotten stuck in the floodwaters (n = 70). However, it is still unclear as to if there is an effect of gender or not. This thesis adds to the literature on the effects of gender on perceived risk regarding a flooded roadway, leaning the literature in favor of gender not having an effect on perceived risk. Since most participants had little past flood experience, they may have relied on trusting the navigation system's warnings and their estimated depth of the flood from the warning more than their own

experiences (Leshed et al., 2008; Johnson et al., 2008). Future research could include participants with a wider range of past flood experience to determine if it does have an effect on actions taken and perceived risk regarding a flooded roadway.

4.5 Vehicle Kinematics

Since this study was run on a driving simulator, a number of vehicle kinematic measures were also recorded without the participant needing to complete extra tasks or questionnaires outside of the required experimental tasks and questionnaires. These measures included the speedometer value, the longitudinal and lateral distance of the vehicle on the road, the acceleration from the gas pedal and brake pedal input, the steering wheel turning angle input, and many more. The speedometer value based on the distance traveled was plotted to show the speed of each driver for each scenario (see Figure 9 and Figure 10). The response time was also calculated and analyzed based on the acceleration from the gas and brake pedal inputs and the steering wheel angle inputs.

From the speed over distance plots, it seems that drivers that turned instead of continuing straight decelerated before the intersection and accelerated after similarly, regardless of the flood information condition. Drivers in the flood scenario had a starting speed of 31 mph at the onset of the flood warning, then dropped their speed under the speed limit of 30 mph about 150 feet after the onset of the warning, reached their lowest speed of 8 mph 5 feet before the beginning of the intersection where they turned, and then reached a speed of 29 mph at the end of the drive. Drivers in the no-flood scenario had a starting speed of 31 mph at the onset of the flood warning, then dropped their speed under the speed limit about 240 feet after the warning, reached their lowest speed of 9 mph 25 feet before the beginning of the intersection, and then reached a speed of 28 mph at the end of the drive. Drivers in the flood of 6 inches scenario had a starting speed of

31 mph, then dropped their speed under the speed limit about 180 feet after, reached their lowest speed of 8 mph 10 feet before the intersection, and finished the drive at 29 mph. Drivers in the flood of 6 inches maximum scenario started at 31 mph, which dropped under the speed limit about 160 feet after, reached their lowest speed of 11 mph 30 feet before the intersection, and finished with a speed of 27 mph.

Drivers in the no-flood scenario decelerated later, but at a higher rate before the intersection, and accelerated earlier and at a higher rate than those in the other three scenarios. This delayed deceleration may be because either option of turning or continuing straight was considered risk-avoidant and deciding between the two was harder than the decisions for the scenarios where a flood was present since the options were so similar (Recarte & Nunes, 2003; Svenson, 1979). Drivers in the flood of 6 inches maximum scenario did not decelerate as much as the other three scenarios but accelerated the slowest after the turn. Drivers in the flood scenario and flood of 6 inches scenario decelerated and accelerated before and after the turn, respectively, similarly.

There was much more speed variability between the flood information conditions for the drivers who continued straight. Drivers in the flood scenario stayed between the speeds of 40 mph from the onset of the flood warning and 24 mph about 30 feet after the end of the intersection. Drivers in the no-flood scenario stayed between the speeds of 32 mph at the start and 30 mph about 100 feet before the intersection. Drivers in the flood of 6 inches stayed between the speeds of 32 mph at the start and 0 mph at the beginning of the intersection. Drivers in the flood of 6 inches maximum scenario stayed between the speeds of 40 mph at the start and 28 mph about 50 feet after the completion of the intersection.

The averaged speeds were much more consistent in the no-flood scenario since it had the largest number of participants that continued straight (*n* = 32; see Figure 10). Drivers in the flood and flood of 6 inches scenarios had a similar dip in speed about 50 feet after the end of the intersection. This may be because the buildings in the environment popped out and generated abruptly rather than inconspicuously in the distance like throughout the beginning of the driving scenario. This happens because the STISIM has to reorient itself after the vehicle makes a turn and has to regenerate the virtual environment (Systems Technology Inc., n.d.). Drivers in the flood of 6 inches maximum scenario had the largest range of speeds because one driver came to a complete stop. Regardless, the other two drivers also drove at much slower speeds than those in the other three flood information conditions that continued straight. This may be because they were cautious about driving through the flood since they estimated the depth to be 5.99 inches, the deepest estimated among the three floods. They may have wanted to drive slower to avoid possible damage to their vehicle (“Tips for dealing with water on the road”, 2022).

One participant in the no-flood scenario who turned, two participants in the flood of 6 inches scenario who both turned, and two participants in the flood of 6 inches maximum scenario, one who turned and one who drove straight, came to a complete stop right before the intersection. It was noted that the participant in the flood of 6 inches scenario who continued straight wanted to back up but was unable to. It is also possible that others wanted to reverse but were unable to like the one participant commented, or that they wanted to have more time to decide what to do. It may have also been their personal driving style, where they treated the intersection as if there were a stop sign. The same participant came to a complete stop in both the flood of 6 inches and flood of 6 inches maximum scenarios before turning.

Response times were collected from the acceleration from the gas and brake pedal inputs and the steering wheel angle inputs and were analyzed based on the flood information condition. The fastest response time from the gas pedal input, brake pedal input, or steering wheel input, was recorded in each scenario for each participant and used for the analysis. Results showed that response times were faster in the flood of 6 inches maximum scenario ($M = 6.79$) than in the no-flood scenario ($M = 7.85$; see Table 7). Both times were after the completion of the flood warning, and during the alert providing the alternate route. This was the only significant pairwise comparison.

The criteria for a response time of 1 m/s^2 acceleration or deceleration for the pedal inputs (Hergeth et al., 2017; Radlmayr et al., 2014) translates to 3.28 ft/s^2, or 2.24 mph, and a change in steering wheel angle of at least two degrees (Hergeth et al., 2017; Radlmayr et al., 2014; Merat et al., 2012) both seemed reasonable. However, some participants did not meet these criteria to have a response time for all three of these input methods. Even though there were 73 participant data analyzed in the study, only 50 participants were analyzed for response times. This is because some participants did not have any measures that met the criteria to count as a response time. There was one participant in the flood scenario who did not meet any of the criteria and thus did not have a recorded response time, 23 in the no-flood condition, and one in the flood of 6 inches maximum condition. Since this was a within-subjects analysis, if a participant was lacking a response time in one of the scenarios, they were not included in the analysis at all since they did not have a complete data set for all four flood information conditions.

Drivers in the no-flood scenario had the slowest response times out of all four flood information conditions while drivers in the flood of 6 inches maximum condition had the fastest response times. The data were not split based on whether they turned or not because there were

not enough data for those who continued straight. Many of the participants who continued straight did not meet the response time criteria and thus did not have a recorded time. The significant response time result reflects mostly participants who chose to accept the alternate route and turn for when they decelerated before the turn. The drivers in the no-flood scenario may have had a slower reaction time because there was no real danger of driving through the flood, and it may have taken them a longer time to decide since both choices are considered risk-avoidant and were similar (Recarte & Nunes, 2003; Svenson, 1979). The drivers in the flood of 6 inches maximum scenario may have had a faster reaction time because they estimated the depth to be 5.99 inches, the largest of the three floods, and that it had the highest perceived risk. Since the scenario had the highest perceived risk, participants may have responded faster to be more cautious and to have more time to make a decision (Dror et al., 1999).

Since the fastest response time was taken from either the gas, brake, or steering wheel input methods, there was not an equal distribution of analyzed response times based on the input method. In the flood scenario, seven times were recorded from the gas pedal input and four were used in the analysis, 42 were from the brake pedal input and 27 were used, and 23 were from the steering wheel input and 19 were used. In the no-flood scenario, five times were from the gas input, 29 were from the brake input, and 16 were from the steering wheel input that were all used in the analysis. In the flood of 6 inches scenario, two times were recorded from the gas and used in the analysis, 49 were from the brake and 30 were used, and 22 were from the steering wheel and 18 were used. In the flood of 6 inches maximum scenario, two times were from the gas and used in the analysis, 43 were from the brake and 27 used, and 27 were from the steering wheel and 21 were used. Most of the response times that were used came from the brake input from when the participant decelerated before the intersection.

Additionally, the steering wheel angle input was not recorded for all 73 participants, unlike the acceleration from the gas and brake inputs. Steering wheel input was recorded for the last 40 participants that were in the analyses. There was a slight oversight in the coding of the driving scenarios, which caused the lack of steering wheel data for the first half of the participants. Even so, most of the recorded responses came from the brake pedal input, followed by the steering wheel input, and lastly the gas pedal input. Based on this trend, if there were steering wheel data for the first half of the participants, it is possible that over half of the recorded response times would still be from the brake pedal input, followed by most of the other responses from the steering wheel input, with only a handful, if any, from the gas pedal input.

4.6 Theoretical Implications

The findings of this thesis deepen the understanding of human decision-making, specifically for drivers when faced with a flooded roadway. It demonstrates how drivers understand and act given flood warnings differing in the amount of information provided, building off the theoretical framework proposed by Chen (2020). The mental model approach to risk communication focuses on how the user thinks about and understands the system through their mental models (Chen, 2020). This study focuses on how laypeople understand and act given different flood warnings with the goal to get a better understanding of their mental models regarding floods and what factors influence their models. Based on the results not supporting Hypothesis 3, it seems that mental models do not necessarily utilize detailed information to be applied to a situation. The mental models for flood warnings may be more of a rough construct rather than a detailed layout.

Even though this study focused on the mental model approach to risk communication, it did have theoretical implications for the information-processing approach as well (Chen, 2020).

By asking participants the depth of the flood, we were able to get a better understanding of how they process the warning information and interpret the depth. For the flood of 6 inches, it seems that people underestimated the depth of the flood, even though the warning gave a direct depth amount. However, by adding in the word “maximum,” drivers were more cautious and estimated the flood to be at the maximum amount given the range. Drivers estimated the depth of the flood to be 6 inches more often when the warning was a range rather than a direct number. This result implies that people process the warnings with more caution when they include a range of values than when given a direct value. It is possible that by providing a range of choices, people consider the worst-possible outcome more, and thus act more cautiously.

The different amount of information given in the warning demonstrates the use of a multi-granularity approach to risk perception in the context of flood warnings. Previous studies used the multi-granularity approach to risk communication in cybersecurity fields (Chen et al., 2018; Jorgensen et al., 2015). This study applied the multi-granularity approach to flood risk communication in a driving simulator scenario and extends the literature on risk communication. The results of this study indicate that the granularity of risk information in the context of flood warnings does not significantly influence the drivers’ decisions regarding driving through a flooded roadway. It shows that participants are not more inclined to avoid the risk when given more information. It is possible that no difference was found between the different granularities because participants estimated the depths of the floods differently than what was set in each scenario. The abstract general flood warning was expected to be estimated at a depth of 6 inches, but instead, participants estimated it at 4.33 inches. The detailed warnings included flood depth information of 6 inches so it could be compared equivalently with the general flood warning, which was expected to be estimated at 6 inches based on our previous online pilot study (Garcia

et al., 2022). Future studies can include flood warnings that state the depth of the flood as 4 inches instead of 6 inches to be equivalent to the estimated 4-inch depth of the general flood scenario in the current driving simulator scenario study.

This study also adds to the literature for several other aspects. Among the flood scenarios, there was no difference in trust in the navigation system based on the flood warnings given. This result adds to the literature on the effects of trust in decision-making regarding a flooded roadway since there is limited research available. Trust was also found to be predicted by perceived risk, supporting prior research (Mayer et al., 1995). However, trust was predicted by perceived risk for only one of the scenarios, the 6-inch maximum scenario. This result may be due to this scenario warning containing the most detail. It seemed that with a consistently high level of trust in the navigation system, people rely on the perceived risk of the scenario more than the trust in the system when deciding if they will drive through the flooded roadway or not. However, this relationship may change if the systems were more different or unreliable and less trusted. Future studies can continue to investigate the effects of perceived risk on trust to gain a clearer relationship. The understanding of the warning was not related to the participants' turn decisions, which adds to the literature on the relationship between understanding warnings and decisions regarding them.

4.7 Design Implications

The results of the current study were mostly expected based on the pilot results and hypotheses (Garcia et al., 2021). However, it was surprising that the granularity of warning information did not affect the actions taken for the flooded roadway as it had previously. This is probably due to the difference in flood depth estimation between the scenarios with a flood. It was intended for the estimations to be the same to test the level of detail of the warning more so

than the flood depth, which was tested in the pilot studies (Garcia et al., 2021; Garcia et al., 2022). Based on the participants' estimated depths for the flood warnings, future studies may update the flood depth included in the warnings to match what was estimated for the abstract general flood scenario.

This study implies that providing any type of flood information is helpful to drivers' decision-making processes. All of the warnings tested conveyed enough information for the driver to know whether there was a flood present or not. This amount of information allowed drivers to be aware of the situation ahead of time and slow down before encountering it. In addition, the alternate route also seemed to help as well (see also Coles & Hirschboeck, 2020). Providing the alternative route may have reduced the stress of the driver to decide since a risk-avoidant solution was provided to them from a trusted source.

This study was conducted through a driving simulator, which generated a virtual partial environment of the vehicle they were driving and the roadway (Systems Technology Inc., n.d.). The driving simulator allowed them to drive in a hazardous scenario without placing themselves in danger while collecting valid data (Underwood et al., 2011; Kaptein et al., 1996; Meuleners & Fraser, 2015). The warning was relayed through both an auditory and visual warning. Based on the response times, it does seem that participants acknowledged the warning and had enough time to make a decision regarding their action. The within-subjects experimental design was advantageous to eliminate individual differences. This includes gender (Drobot et al., 2007), past flood experience (Pearson & Hamilton, 2014), driving style (Bianchi & Summala, 2004), and personality type (Classen et al., 2011), which all could have influenced the participants' decision-making regarding the flooded roadway. Future warning systems should provide the driver ample time to decide before encountering the intersection before the flood, as well as be

relayed through both auditory and visual media. Future studies should continue to use a driving simulator with both visual and auditory warnings for a within-subjects design to collect valid data without putting the participant in harm's way, have the participant acknowledge the warning, and to eliminate individual differences in the data.

4.8 Practical Implications

By researching how people understand and interpret flood warnings, revised designs for flood warnings can be created to better fit their mental models so they may display appropriate risk-avoidant responses. We found that the level of detail in the warning did not significantly influence their decisions regarding the flood. A warning containing enough information for the participant to understand whether a flood was present or not was sufficient. Drivers judged the flood of 6 inches maximum warning to have an estimated flood depth of 6 inches more often than the flood of 6 inches warning. By adding the word "maximum" to the warning, drivers were more cautious and had a higher estimated flood depth. In the flood scenarios, an alternate route was always provided, which may have made the decision-making process easier for the drivers, since there was an available alternate route for them to take to avoid the flood. For flood warnings, designers should relay enough information to convey that there is a flood and provide an alternate route to encourage drivers to make risk-avoidant decisions. If designers want to relay the depth of the flood, then they should include a range of values so people may better understand the extent of the flood depth and estimate it to be the deepest amount within the range.

4.9 Study Limitations and Future Research

This study had several limitations which may have influenced the actions taken by the participants regarding the flooded roadway. First, in the practice drive, they were instructed to

"follow traffic rules and GPS instructions" which may have primed participants to continue to follow the instructions by the navigation system in the following scenarios. This may be the reason why there was no significant difference between the general flood scenario and the flood scenarios that contained flood depth information like it did in the pilot study (Garcia et al., 2021). However, for each flood information condition, the navigation system did say, "an alternate route has been found, if you accept, turn right/left at the next intersection." It was optional for the participants to accept the alternate route provided by the navigation system. Future studies can ensure that the participants are not primed to follow the navigation instructions from the practice drive. It should be emphasized that the participant should do what they believe is best in the scenario, which can either be taking the alternate route or driving through the flooded roadway.

Another restriction is that there were limited steering wheel input data from participants. Only the last 40 participants included in the analyses had steering wheel angle input data due to an oversight with the driving simulator scenario coding. However, based on the available response time data, it is forecasted that the percentage of response times from the steering wheel input would be similar to what was found in this study. Future studies should ensure that all vehicle kinematics data that will be used in the analyses are collected for all participants. This inclusion can allow for more data to be analyzed for response times for drivers continuing straight since there were limited data collected for these participants to run an additional analysis based on action taken. Alternatively, different response time criteria may be used to record times for those who continue straight. For example, those who continue straight may not use their brake as drastically as those that turn, so a more sensitive measure of acceleration from the gas and brake input may be needed.

The participants also had relatively low past flood experience of driving through flooded roadways. This small range may be why past flood experience was not a significant predictor in the analyses. Future studies could specifically sample participants in different climate areas that have a wider range of past flood experience to fully test the effect of past flood experience.

One constraint is that all of the flood information conditions followed a very similar route. In each scenario, the participant had to continue to drive straight until they received the flood warning. It is possible that the participants expected the warning after a certain amount of time in the scenario. However, each scenario varied in the distance they had to drive in order to receive the warning, so it is unlikely that they knew exactly when it would appear. In addition, participants saw the scenarios in different orders based on the Latin square design. Regardless, participants may have anticipated a warning to appear after a certain point, which may have influenced the response times and their speed in the latter half of the scenarios.

Another limitation is that this study was conducted in a driving simulator rather than in an actual vehicle on a flooded roadway. A driving simulator was used to increase the external validity of this study from the pilots, which were conducted through surveys (Garcia et al., 2021; Garcia et al., 2022). Even though the driving simulator is the best and safest alternative currently available, there may be less urgency than in real-life. Future studies can include observational studies of drivers encountering a flooded roadway to see what their actions are in a real-life situation.

Lastly, the destination was the same throughout all four scenarios. A neutral destination, such as a restaurant, which has neither a high nor low urgency associated with it, was used for this experiment. The destination may have an effect on the drivers’ motivation to drive through the flooded roadway or not. It may alter the purpose of the drive and the importance the

participant places on the driving task. For example, a participant may be more motivated to drive through a flooded roadway to reach the hospital than if they were driving to the grocery store. Future studies can examine whether the destination given to the participant influences their actions by including different locations to drive to.

From this thesis, several future studies can be conducted to examine several discoveries made. First, they can include flood warnings that include the depth of the flood at 4 inches in depth in a driving simulator scenario study. Since the estimated flood depth for the general flood scenario was 4.33 inches instead of the predicted 6 inches, it was difficult to compare the level of detail of the warning since the perceived depths were unequal among the scenarios that contained a flood. When analyzing the level of detail of the warning, it would be advantageous to have the detailed flood warnings that contain the flood depth be equally estimated to the abstract flood warning in terms of flood depth and be set at 4 inches. Second, studies can continue to investigate the effects of perceived risk on trust to gain a clearer relationship. The results in this study only showed perceived risk from one of the flood information conditions to predict trust. Third, future studies should use a driving simulator with both visual and auditory warnings for a within-subject design when studying flood warning decision-making. Data from the driving simulator is valid, the participants acknowledged the warning based on their response times, and the study design eliminated individual differences which may influence decision-making.

CHAPTER 5

CONCLUSIONS

Flood warnings are integral to communicating risk to the public and allowing them to make decisions to stay safe. This thesis tested the effect of the level of detail included in flood warnings on decisions regarding driving through a flooded roadway. The purpose of this thesis was to extend prior research, deepen the understanding of human decision-making, and investigate how to best design flood warnings to encourage risk-avoidant responses. In addition to detail level of the flood warning, past flood experience, perceived risk, and gender were also examined as factors that affect driving decisions, understanding of the situation, and trust in the navigation system. Participants manually drove a vehicle in a driving simulator and experienced four different flood information condition warnings with varying levels of detail (flood, no flood, flood of 6 inches, flood of 6 inches maximum) given by a mobile navigation system throughout four driving scenarios. Results showed that participants displayed more risk-avoidant actions in any scenario with a flood present compared to the no-flood scenario. However, the level of detail of the warning did not influence the actions taken regarding the flooded roadway. Trust was not significantly different between flood information conditions. The perceived risk may have been based on the estimated flood depth relayed by the warning rather than the level of detail of the warning. Gender and past flood experience did not predict the actions taken, understanding, or trust, but perceived risk did partially predict trust. Overall, this thesis adds to the flood decision-making literature as well as shows that detailed flood warnings are just as effective as general flood warnings for encouraging risk-averse responses.

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APPENDIX A

MOTION SICKNESS SUSCEPTIBILITY QUESTIONNAIRE SHORT-FORM (MSSQ-SHORT)

This questionnaire is designed to find out how susceptible to motion sickness you are, and what sorts of motion are most effective in causing that sickness. Sickness here means feeling queasy or nauseated or actually vomiting.

Your childhood experience only (before 12 years of age), for each of the following types of transport or entertainment please indicate

1. As a child (before age 12), how often you **felt sick or nauseated** (tick boxes).

	Not Applicable – Never Traveled	Never Felt Sick	Rarely Felt Sick	Sometimes Felt Sick	Frequently Felt Sick
Cars					
Buses or Coaches					
Trains					
Aircraft					
Small Boats					
Ships, e.g. Channel Ferries					
Swings in playgrounds					
Roundabouts in playgrounds					
Big Dippers, Funfair Rides					
	t	0	1	2	3

Your experience over the last 10 years (approximately), for each of the following types of transport or entertainment please indicate

2. **Over the last 10 years,** how often you **felt sick or nauseated** (tick boxes).

	Not Applicable - Never Traveled	Never Felt Sick	Rarely Felt Sick	Sometimes Felt Sick	Frequently Felt Sick
Cars					
Buses or Coaches					
Trains					
Aircraft					
Small Boats					
Ships, e.g. Channel Ferries					
Swings in playgrounds					
Roundabouts in playgrounds					
Big Dippers, Funfair Rides					
	t	0	1	2	3

APPENDIX B

QUESTIONS TESTING FOR UNDERSTANDING

1. Based on the scenario that you just experienced, where are you located when you open up your GPS mobile application?
    a. At home
    b. In the car
    c. At a friend’s
    d. In a taxi
    e. Did not say
2. Based on the scenario that you just experienced, what kind of vehicle do you have?
    a. SUV (Toyota Highlander)
    b. Sedan (Honda Civic)
    c. Sports car (Mustang)
    d. Motorcycle (Harley)
    e. Did not say
3. Based on the scenario that you just experienced, which of the following best describes the nature of the flood situation?
    a. There was a flood (with no specific depth) expected on my route
    b. There was no flood expected on my route
    c. There was a flood of 6 inches expected on my route
    d. There was a flood of 6 inches maximum expected on my route
    e. There was a flood of 4 inches expected on my route
    f. There was a flood of 4 inches maximum expected on my route

   g. Did not say

4. In the scenario described, how would you estimate the depth of the water?
   a. Depth in inches _____

APPENDIX C

PERCEIVED RISK QUESTIONNAIRE

The following questions are about how you perceive the level of risk associated with continuing straight during the drive you just experienced.

I believe that…

1. The consequences for continuing straight in this scenario is substantial.

Not descriptive: 1 2 3 4 5 6 7 8 9 10 11 12 : Very Descriptive

2. The overall risk of continuing straight in this scenario is high.

Not descriptive: 1 2 3 4 5 6 7 8 9 10 11 12 : Very Descriptive

3. Overall, I would label the consequences of continuing straight in this scenario as something negative.

Not descriptive: 1 2 3 4 5 6 7 8 9 10 11 12 : Very Descriptive

4. I would label the consequences of continuing straight in this scenario as a significant loss.

Not descriptive: 1 2 3 4 5 6 7 8 9 10 11 12 : Very Descriptive

5. Continuing straight in this scenario could have negative ramifications.

Not descriptive: 1 2 3 4 5 6 7 8 9 10 11 12 : Very Descriptive

APPENDIX D

TRUST QUESTIONS

For the following questions, please indicate your agreement with each statement from 1 (not at all) to 7 (extremely). These questions are for the GPS system in the scenario that you just experienced.

Please pick which best describes your feeling or your impression.

1. The GPS system is deceptive

Strongly disagree: 1 2 3 4 5 6 7 :Strongly agree

2. The GPS system behaves in an underhanded manner

Strongly disagree: 1 2 3 4 5 6 7 :Strongly agree

3. I am suspicious of the GPS system's intent, action, or outputs

Strongly disagree: 1 2 3 4 5 6 7 : Strongly agree

4. I am wary of the GPS system

Strongly disagree: 1 2 3 4 5 6 7 : Strongly agree

5. The GPS system's actions will have a harmful or injurious outcome

Strongly disagree: 1 2 3 4 5 6 7 : Strongly agree

6. I am confident in the GPS system

Strongly disagree: 1 2 3 4 5 6 7 : Strongly agree

7. The GPS system provides security

Strongly disagree: 1 2 3 4 5 6 7 : Strongly agree

8. The GPS system has integrity

Strongly disagree: 1 2 3 4 5 6 7 : Strongly agree

9. The GPS system is dependable

Strongly disagree: 1 2 3 4 5 6 7 : Strongly agree

10. The GPS system is reliable

Strongly disagree: 1 2 3 4 5 6 7 : Strongly agree

11. I can trust the GPS system

Strongly disagree: 1 2 3 4 5 6 7 : Strongly agree

12. I am familiar with the GPS system

Strongly disagree: 1 2 3 4 5 6 7 : Strongly agree

APPENDIX E

POST-EXPERIMENT QUESTIONS

1. What is your primary mode of transportation?
   a. Car
   b. Motorcycle
   c. Bus
   d. Train
   e. Bicycle
   f. Other ________
2. How often does it flood in the location you currently reside in?
   a. Never
   b. Rarely
   c. Occasionally
   d. Sometimes
   e. Frequently
   f. Usually
   g. Every time
3. What is your age?
4. What is your gender?
   a. Male
   b. Female
   c. Non-binary
   d. Prefer not to say

e. Prefer to self-describe _________

5. Choose one or more ethnicities that you consider yourself to be:

    a. Caucasian, Non-Hispanic
    b. Black, Non-Hispanic
    c. Native American/Alaskan
    d. Asian/Pacific Islander
    e. Hispanic
    f. Other/Unknown ________

6. What is the highest degree or level of education you have completed?

    a. Less than high school
    b. High school graduate (high school diploma or equivalent including GED)
    c. Some college but no degree
    d. Associate degree in college (2-year)
    e. Bachelor's degree in college (4-year)
    f. Master's degree
    g. Doctoral degree
    h. Professional degree (JD, MD)

7. At which age did you obtain your first driver's license?

8. On average, how often do you drive a vehicle in a typical year (12 months)?

    a. Never
    b. Once a month
    c. 2-3 times a month
    d. Once a week

e. 2-3 times a week

f. 4-6 times a week

g. Daily

9. On average, about how many miles do you drive in a typical year (12 months)?

10. What brand of vehicle do you drive most frequently?

11. What type of vehicle do you drive most frequently?

12. What year of construction is the vehicle you drive most frequently?

13. How often have you driven through a flooded roadway in the past?

    a. Never

    b. Rarely

    c. Occasionally

    d. Sometimes

    e. Frequently

    f. Usually

    g. Every time

14. If you have driven through a flooded roadway in the past, how often have you gotten stuck in the floodwater?

    a. Never

    b. Rarely

    c. Occasionally

    d. Sometimes

    e. Frequently

    f. Usually

g. Every time

15. How many times have you gotten stuck in the floodwater in the past?

16. Which GPS mobile application do you use most frequently?

a. Google Maps

b. Waze

c. Apple Maps

d. Other _______

e. I have never used a GPS mobile application before

17. What depth of water do you think this vehicle can drive through?

a. Depth in inches ______

18. Do you have any comments regarding this survey?

APPENDIX F

A-PRIORI POWER ANALYSIS FROM G*POWER FOR ONE COMPARISON

z tests - Logistic regression

Options:	Large sample z-Test, Demidenko (2007) with var corr		
Analysis:	A priori: Compute required sample size		
Input:	Tail(s)	=	One
	Odds ratio	=	0.117
	Pr(Y=1|X=1) H0	=	0.739
	α err prob	=	0.05
	Power (1-β err prob)	=	0.8
	R^2 other X	=	0.25
	X distribution	=	Binomial
	X parm π	=	0.5
Output:	Critical z	=	-1.6448536
	Total sample size	=	36
	Actual power	=	0.8102951

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SELECT PUBLICATIONS, CONFERENCE PROCEEDINGS, AND PRESENTATIONS

Accepted Article Publication

Garcia, K., Mishler, S., Xiao, Y., Wang, C., Hu, B., Still, J., & Chen, J. (in press). Drivers' understanding of Artificial Intelligence in autonomous vehicles: A case study of malicious stop signs. *Journal of Cognitive Engineering and Decision Making*.

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