Proceedings of the 2025 Winter Simulation Conference
E. Azar, A. Djanatliev, A. Harper, C. Kogler, V. Ramamohan, A. Anagnostou, and S. J. E. Taylor, eds.

THE INFLUENCE OF INFORMATION SOURCE AND MODALITY ON FLOOD RISK PERCEPTION AND PREPAREDNESS

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ABSTRACT

Flood risk communication influences how the public perceives hazards and motivates preparedness actions, like taking preventive measures, purchasing insurance, and making informed property decisions. Prior research suggests that both the format and source of information can influence how people interpret risk. This study investigates how flood map types and sources influence individuals' risk perception and decision-making. Using a randomized control trail ($N = 796$), participants were assigned to view one of the several flood risk representations sourced from governmental agencies, a nonprofit, and crowdsourced images of past floods, or plain geographical maps. Participants then self-reported their risk perceptions and behavioral intentions. This study compares visual formats and sources to reveal how communication strategies influence public understanding and preparedness, guiding more effective flood risk messaging.

1 INTRODUCTION

Effective risk communication plays a critical role in disaster preparedness and response. This communication is often shaped by how the risk is assessed and understood. Although risk assessment typically emphasizes outcome magnitude and likelihood, individuals often make decisions under time constraints and limited information, rendering strict reliance on quantitative data impractical. In such cases, decision-making frequently depends on expert judgment and intuition rather than purely logical analysis. For example, individuals may decide to buy health insurance based on social norms and trust rather than a clear understanding of actual costs and benefits (Zinn 2008). This subjective risk perception can be further influenced by emotional responses such as fear and anxiety.

The psychological mechanisms underlying risk perception, including mental imagery, play a key role in shaping how individuals assess and respond to risk, as visualizing potential hazards can shape how severe individuals perceive them to be. In this context, the vividness of mental imagery, defined by its dynamism, intensity, and realism, may indirectly shape risk perception (Zaleskiewicz et al. 2023). Imagery can engage any of our senses, enabling us to mentally recreate past experiences and envision future scenarios (a.k.a., mental time travel) (Andrade et al. 2014). This sensory engagement does not merely enhance memory and imagination; it can also shape how we interpret and respond to information. Research has also found that modality, the sensory channel through which information is conveyed, significantly influences the perception of risk and subsequent decision-making behavior (Lin 2023, Geipel et al 2023, Sanni et al. 2024). The effect of different modalities (i.e., visual, auditory, olfactory, and tactile) has been extensively investigated across various domains. In project risk management, for example, effective visualization of information enhances risk perception and improves decision-making behavior; yet, a key challenge lies in the visual presentation of risk information, as it significantly affects perception and judgments (Dikmen et al. 2024). Research suggests that representing uncertainty through visual cues, e.g., color-coded threat indicators, encourages more cautious decision-making. For instance, in a simulated minefield navigation exercise, participants relying on visual representations opted for safer yet more time-consuming routes compared to those using auditory or tactile cues (Basapur et al. 2003). In high-stakes domains such as finance, military operations, and medicine, the interaction of multiple sensory modalities, particularly auditory and visual inputs, can complicate risk perception (Payzan-LeNestour et al. 2021).

To date, research on the role of modality in flood risk communication remains limited. Understanding how information modality influences the formation and calibration of flood risk perception is increasingly critical given the rising frequency and severity of flooding globally. In this context, the way flood data is presented, whether through maps, photos, or other formats, can significantly shape risk perception. While visual representations are commonly used in flood risk communication, their effectiveness varies. For instance, Houston et al. (2019) explored the impact of different hazard maps by randomly assigning participants to view either a Federal Emergency Management Agency (FEMA) map, which represented flooded areas with a single color and less spatial differentiation, or a Flood Resilient Infrastructure and Sustainable Environments (FloodRISE) map, which depicted flood depth with a gradation of colors at a street scale. Results showed that spatial awareness increased among all participants (regardless of sociodemographic status or geographical location) after viewing the maps. However, participants viewing FEMA maps had lower spatial awareness than those viewing FloodRISE maps.

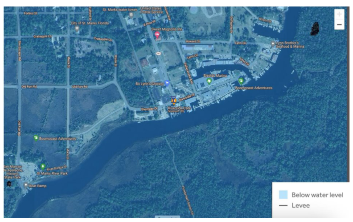
Prior work shows that sociodemographic factors and prior flood experience shape how people perceive and respond to flood risk information. One such finding is that women tend to express more concern about impacts on home and family, while men focus more on economic risks (Houston et al. 2019; Kellens et al. 2011; Gustafson 1998). In a study of 17 risk categories, female respondents rated hazard risks (e.g., flood, drought, storm) significantly higher than their male counterparts, except for fire events, where men perceived a greater impact (Brown et al. 2021). Similarly, prior flood experience appears to heighten perceived risk and improve spatial awareness, particularly among younger, lower-income, and short-term residents (Houston et al, 2019). In addition, higher income and education levels are found to be associated with lower perceived risk (Flynn et al. 1994), whereas older adults tend to report higher perceived risk (Sattler et al. 2000; Peacock et al. 2005; Bodas et al. 2022).

Considering these prior findings on the influence of source, modality, and demographics on risk perception and decision making, the research presented in this paper will address three research questions. First, we explore whether perceived flood risk severity remains consistent across different flood risk map sources (e.g., FEMA, NOAA, Climate Central) and modalities (e.g., images vs. maps). Next, we assess whether gender plays a role in the decision to purchase or rent property when individuals are presented with different flood risk visualizations. Finally, we examine whether property purchase and rental decisions, and how participants interpret visual flood risk information, vary by education level. Understanding these factors can provide insights into how individuals interpret flood risk information and make property-related decisions. Identifying patterns in risk perception and decision-making can enhance the effectiveness of flood risk communication, ensuring accessibility and relevance for all populations.

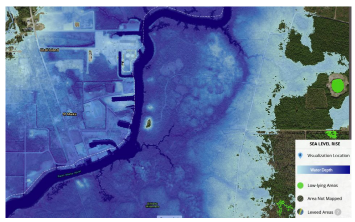
2 METHODOLOGY

2.1 Research Design

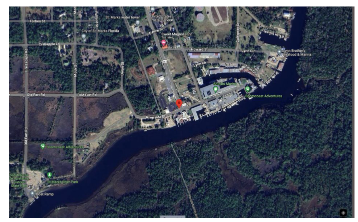
We employ a quantitative approach, using a randomized controlled trial (RCT) experiment on Qualtrics to assess how individuals perceive flood risk based on different flood map sources and modalities. Flood map information is grouped into five distinct categories. Four of these categories contain map screenshots from established flood mapping sources, namely FEMA, National Oceanic and Atmospheric Administration (NOAA), Climate Central, and Google Maps. The fifth category consists of real-world flood images, collected in one of our previous studies (Alizadeh Kharazi 2023). Since Google Maps does not present any explicit flood risk information, obtained map screenshots from this source serve as a visual baseline or control group. This distinction in source and modality allows us to examine how individuals interpret flood risk differently when presented with abstract, map-based representations versus actual photographic evidence. A total of 260 U.S. locations were selected for analysis, and corresponding flood map screenshots were extracted from FEMA, NOAA, Climate Central, and Google Maps to ensure consistent geographic coverage. Figure 1 presents a sample entry from Wakulla County, Florida. To ensure a broad and diverse representation of individuals, participants were recruited via Amazon Mechanical Turk (MTurk), and randomly assigned to one of the five visualization groups using Qualtrics' built-in randomizer. Within each group, participants were shown two images selected at random from the pool of 260 U.S. locations using Qualtrics' randomization logic. Following the visual exposure, participants completed a structured survey about their sociodemographic status (age, gender, education level, location), flood experience (past flood exposure, preparedness actions taken, familiarity with flood maps), and flood risk perception and resulting behavioral intentions. Individual responses are coded using 5-point Likert-scales (ranging from options such as 'very likely' to 'very unlikely'), allowing for a standardized measurement of the outcomes.



(a) Flood extent map generated using Climate Central's Coastal Risk Screening Tool. The flood extent corresponds to a 10-meter sea level rise scenario.



(b) Sea-level rise visualization from NOAA's SLR Viewer. The map depicts projected inundation under a 10-meter sea level rise.



(c) Satellite imagery from Google Maps, shown to participants as a baseline visual of the area. This view includes no explicit flood overlay.

(d) FEMA flood hazard map from the NFHL Viewer. The map indicates zones of risk under a 10-meter base flood elevation scenario.

(e) Crowdsourced flood photo from NOAA's BluPix dataset. This image illustrates real-world flood conditions.

Figure 1: Flood risk visualizations for a location in Wakulla County, Florida, used across five experimental groups. Each panel presents a different source or modality of flood risk information.

2.2 Participants

The study is approved by the Institutional Review Board (IRB). We follow all ethical research guidelines to ensure that participants are fully informed about the study's purpose and procedures before participation and provide necessary consents. Participation was restricted to individuals aged 18 and older who resided in the United States. Participants were recruited via MTurk, and study data were collected using Qualtrics over a one-month period between September and October 2024. As listed in Table 1, the final sample includes individuals from different age groups, genders, and educational backgrounds. Most participants (58%) were between 25 and 35 years old. Gender distribution includes 29.3% female and 70.6% male. Educational background varied, with 66.8% of participants holding a bachelor's degree, followed by master's degree (22.5%). A strong majority (94.6%) of participants had past experience with floods, and only 5.4% had no such experience. Table 1 also compares the study sample's demographic distribution with that of the general U.S. population to assess representativeness. While the sample's racial composition aligns with national demographics, it skews toward younger, more male, and more highly educated individuals. This sampling bias represents a limitation of the study, particularly given the central role of demographic characteristics in analyzing flood risk perception. As such, findings should be interpreted with caution when generalizing to the broader U.S. population. Table 2 shows the distribution of participants across visualization category. As previously mentioned, participants viewed two images from different locations within their assigned category. For each image, participants answer a set of questions related to understanding the perception of risk, such as perceived flood severity, frequency of flooding, confidence in information, and ease of interpretation. Additional questions focus on behavioral intentions, such as the likelihood of purchasing flood insurance, likelihood of buying or renting property in the area, and likelihood of taking preventive actions.

Table 1: Demographic distribution of the study sample compared to the U.S. population. Percentages for the U.S. population are based on adults aged 18 and over. All population data are sourced from the U.S. Census Bureau and reflects estimates from 2022 to 2024.

Variables	**Sample (%)**	**Population (%)**	**Variables**	**Sample (%)**	**Population (%)**
Gender			Education		
Male	70.6	48.8	High school graduate or less	2.5	38.7
Female	29.4	51.2	Some college	3.8	16.5
Race			Associate degree	2.4	9.9
White alone	75.4	75.3	Bachelor's degree	66.8	22.1
Black alone	2.8	13.7	Master's degree	22.5	9.5
American Indian and Alaska Native	3.3	1.3	Doctoral or other professional degree	2.0	3.3
Asian alone	13.4	6.4	Age		
Native Hawaiian or Pacific Islander	0.3	0.3	18 to 24	8.2	16.2
Two or more races	4.8	3.1	25 to 34	58.0	16.6
Hispanic or Latino	45.7	19.5	35 to 44	20.5	16.0
White alone, not Hispanic or Latino	48.3	58.4	45 to 54	9.2	14.7
			55 to 64	3.1	15.2
			65 or over	1.0	21.3

Table 2: Distribution of participants by flood risk visualization conditions.

Source	**Count**	**% of sample**
FEMA	170	21.36
NOAA	142	17.84
Climate Central	162	20.35
Google Maps	156	19.60
Flood Image	166	20.85
Total	796	100.00

2.3 Methods of Analysis

This study focuses on four key behavioral intention variables: (1) likelihood to buy property, (2) likelihood to rent property, (3) likelihood to buy flood insurance, and (4) likelihood to take preventive actions. These outcomes capture how different visualizations influence respondents' decision-making. Each response variable is measured on a 5-point Likert-style scale, with numerical values assigned to ordinal categories for analysis. For instance, in questions assessing behavioral intent (e.g., likelihood to buy property), responses ranged from 1= 'very likely' to 5 = 'very unlikely', where lower values indicate a stronger likelihood of action. Similarly, for perception-based questions (e.g., flood risk severity), the scale ranged from 1 = 'very high' to 5 = 'very low', where lower values reflect higher perceived risk. For statistical testing, assumptions of parametric tests (e.g., ANOVA), such as normality and homogeneity of variances, are often violated when applied to ordinal data. Therefore, we employ the Kruskal-Wallis H-test, a non-parametric alternative to ANOVA that does not assume normal distribution and is better suited for analyzing ordinal response variables (Hecke 2010). To evaluate differences in participant responses across different groups, we use the Kruskal-Wallis H-test, a non-parametric test appropriate for Likert-scale data. Where significant group differences are observed, Dunn's post-hoc test with Bonferroni correction is applied to determine which specific modality or source pairs differ significantly.

To examine whether gender influences behavioral intentions in response to flood risk visualizations, a two-step non-parametric analysis is conducted. First, the Mann-Whitney U-test is used to assess overall differences between male and female participants across four key behavioral intention variables. Next, Kruskal-Wallis H-tests are conducted separately for male and female participants to explore whether gender-based behavioral differences vary by flood map modality and source. For gender groups showing significant differences, Dunn's post-hoc tests with Bonferroni correction were used to identify specific visualization pairs that differed. This two-step analysis provided both an overall view of gender differences and a detailed understanding of how these differences appeared across flood risk visualizations.

To examine whether age influences behavioral responses to flood risk visualizations, participants were grouped into three age categories of young (18-34 years), middle-aged (35-54 years), and older (55+ years) adults, based on the overall sample distribution (see Table 1). Behavioral intent in each age group is assessed using responses to the four key variables. Kruskal-Wallis H-test is used to decide whether significant differences in responses exist among the age groups. Where significant effects are observed, Dunn's post-hoc tests with Bonferroni correction are applied to identify specific pairs of age groups with meaningful differences. To further explore whether the impact of age on behavioral intent varies by visualization type, subgroup analyses are conducted within each age category. Kruskal-Wallis tests are run separately for each group to compare responses across different flood risk visualization types. Where significant modality effects are found, pairwise Dunn's tests are used to identify specific differences between visual formats. This two-tiered approach allows us to isolate both general age effects and age-specific responses to different visualizations.

Finally, to assess whether education level influences behavioral responses to flood risk visualizations, participants' reported education levels are consolidated into three categories of 'Some college or less' (those with a high school diploma or less, some college, or an associate degree), 'Bachelor' (those with a bachelor's degree), and 'Graduate' (those holding a master's or doctoral/professional degree). This grouping ensures sufficient sample sizes within each category while preserving meaningful distinctions in educational attainment. Behavioral intent in each age group is assessed using responses to the same four key variables. The Kruskal-Wallis H-test is used to evaluate whether statistically significant differences in behavioral intent exist across the three education categories. When group-level differences are significant, Dunn's post-hoc test with Bonferroni correction is conducted to identify which specific education-level pairs differ. Additionally, to explore whether individuals within each education group responded differently to different flood risk visualization types, Kruskal-Wallis tests are conducted within each group. For education categories that show significant modality effects, follow-up Dunn's tests are performed to determine which visualization types contributed to the observed differences.

3 RESULTS

3.1 Effect of Modality and Source

To evaluate the impact of map source and modality on risk perception and behavior, a Kruskal-Wallis H-test was conducted across five visualization types. As shown in Table 3, significant differences were found for perceived flood severity ($H(4) = 23.772$, $p < 0.001$) and confidence in interpretation ($H(4) = 12.802$, p

= 0.012). No statistically significant differences were observed for the remaining variables. Post-hoc comparisons using Dunn's test with a Bonferroni correction revealed significant differences in how participants perceived flood risk severity and their confidence in interpreting the flood risk visualization. For flood risk severity, participants who viewed NOAA, Climate Central, and Google Maps reported significantly higher median scores than those who viewed Flood Images (p = 0.004, 0.012, and < 0.001, respectively). Since higher median values correspond to lower perceived severity on the Likert scale, these results suggest that Crowdsourced Images conveyed a stronger sense of flood risk severity compared to traditional map formats. Additionally, for confidence in interpreting the map, participants who viewed Google Maps had a significantly higher median score than those who viewed Climate Central maps (p = 0.009). Since lower Likert values correspond to greater confidence, this indicates that participants felt more confident interpreting Climate Central than Google Maps. No other significant differences were found among FEMA, NOAA, or Flood Image modalities for confidence scores (Table 4). These findings suggest that photographic flood imagery heightened perceptions of severity but did not significantly affect participants' understanding or ease of interpretation. This suggests that while emotional impact varies by visual type, comprehension remains consistent across modalities.

Table 3: Kruskal-Wallis H-test examining differences across flood risk visualizations.

Variable	***H*-statistic**	***df***	***p*-value (* statistical significance)**
Flood risk severity	23.772	4	< 0.001*
Flood risk understanding	3.150	4	0.533
Confidence in interpretation	12.802	4	0.012*
Ease of interpretation	2.759	4	0.599
Likely to buy property	6.261	4	0.180
Likely to rent property	3.807	4	0.433
Likely to buy insurance	2.652	4	0.618
Likely to take preventive actions	2.428	4	0.658

Table 4: Dunn's post-hoc pairwise comparisons across flood risk visualizations. Adjusted p-values are reported using Bonferroni correction. Only significant values are reported.

Pairwise difference	**Adjusted *p*-value (* statistical significance)**
Flood Risk Severity	
Climate Central – Flood images	0.012*
Google maps – Flood images	< 0.001*
Flood images – NOAA	0.004*
Confidence in map image	
Climate Central – Google maps	0.009*

3.2 Effect of Gender

To examine whether gender influences behavioral intentions in response to flood risk visualizations, Mann-Whitney U-tests were conducted across five flood risk visualization types, with results indicating no statistically significant differences between male and female participants across any of the risk perception and behavioral response variables (Table 5). This finding suggests that gender, in aggregate, did not have a significant effect on behavioral intents. To further examine whether the source and modality of flood risk visualization interacted with gender to influence these responses, Kruskal-Wallis H-tests were performed separately for male and female participants across flood risk visualizations (Table 6). Among male participants, no significant differences were observed across modalities for any behavioral response. However, significant differences emerged for female participants in their likelihood to buy property ($H(4) = 15.642$, $p = .004$) and likelihood to rent property ($H(4) = 15.887$, $p = 0.003$), suggesting that they were more sensitive to the type of flood risk visualization shown. To identify which specific modality pairs contributed to these differences among female participants, Dunn's post-hoc tests with Bonferroni correction were conducted. It was found that female participants who viewed FEMA maps reported significantly higher intention to buy property compared to those who viewed Flood Images ($p = 0.002$). Similarly, NOAA maps were associated with higher purchase intent compared to Flood Images ($p = 0.047$). A similar pattern was observed for renting intentions, where FEMA maps led to significantly higher likelihood to rent compared to Flood Images ($p = 0.003$). These findings suggest that female participants expressed lower willingness to buy or rent property when exposed to image-based visualizations, which may reflect a heightened perception of flood risk. This effect was not seen in male participants, pointing to a gender-specific response to visualizations.

Table 5: Mann-Whitney U-test comparing Likert-scale responses across gender groups.

Variable	***U*-statistic**	***z- score***	***p*-value (* statistical significance)**
Likely to buy property	256379.5	-0.794	0.408
Likely to rent property	261257.5	-0.210	0.827
Likely to buy insurance	264854.0	0.220	0.818
Likely to take preventive actions	260554.0	-0.295	0.758

Table 6: Kruskal-Wallis H-test comparing gender differences across flood risk visualizations.

Variable	***H*-statistic**	***df***	***p*-value (* statistical significance)**
Male			
Likely to buy property	1.839	4	0.765
Likely to rent property	1.179	4	0.881
Likely to buy insurance	7.421	4	0.115
Likely to take preventive actions	3.038	4	0.552
Female			
Likely to buy property	15.642	4	0.004*
Likely to rent property	15.887	4	0.003*
Likely to buy insurance	4.937	4	0.294
Likely to take preventive actions	4.707	4	0.319

3.3 Effect of Age

To explore the influence of age on participants' behavioral responses to flood risk visualizations, Kruskal-Wallis H-tests were conducted using three age categories of young (18-34 years), middle-aged (35-54 years), and older (55+ years) adults. As shown in Table 7, statistically significant differences were found across age groups for the likelihood to buy property ($H(2) = 17.901$, $p < 0.001$) and rent property ($H(2) = 22.710$, $p < 0.001$), while no significant differences were observed for the likelihood to buy flood insurance or take preventive actions. Dunn's post-hoc results in Table 8 reveal that older adults reported significantly lower willingness to buy property compared to young adults ($p < 0.001$) and middle-aged adults ($p = 0.020$). Similarly, older adults were significantly less likely to rent property than both young adults ($p < 0.001$) and middle-aged adults ($p = 0.047$), with middle-aged adults also differing significantly from young adults ($p = 0.004$). These patterns suggest that older participants were less inclined to engage in property-related decisions in areas perceived as flood-prone, which may indicate greater sensitivity to perceived risk or more cautious decision-making. To further explore how these age-related patterns varied across modalities, Kruskal-Wallis H-tests were run within each age group. As shown in Table 9, older adults' behavioral responses varied significantly by visualization modality, particularly in their willingness to buy property ($H(4) = 20.907$, $p < 0.001$) and rent property ($H(4) = 15.806$, $p = 0.003$). Post-hoc comparisons using Dunn's test with a Bonferroni correction showed that older adults were significantly less likely to buy or rent property after viewing flood images compared to all flood maps, i.e., Climate Central ($p < 0.001$ for buying; $p = 0.007$ for renting), FEMA ($p = 0.014$ and 0.011), NOAA ($p = 0.034$ and 0.085), and Google Maps ($p = 0.031$ for buying). These results highlight that flood images may have a particularly strong effect on older adults' behavioral intentions in high-risk flood zones.

Table 7: Kruskal-Wallis H-test comparing Likert-scale responses across age groups.

Variable	*H*-statistic	*df*	*p*-value (* statistical significance)
Likely to Buy Property	17.901	2	< 0.001*
Likely to Rent Property	22.710	2	< 0.001*
Likely to Buy Flood Insurance	1.707	2	0.426
Likely to Take Preventive Actions	2.410	2	0.300

Table 8: Dunn's post-hoc test comparing pairwise differences across age groups.

Pairwise difference	Adjusted *p*-value (* statistical significance)
Likely to buy property	
Young Adults – Middle-Aged Adults	0.061
Young Adults – Older Adults	< 0.001*
Middle-Aged Adults - Older Adults	0.020*
Likely to rent property	
Young Adults – Middle-Aged Adults	0.004*
Young Adults – Older Adults	< 0.001*
Middle-Aged Adults – Older Adults	0.047*

Table 9: Kruskal-Wallis H-test comparing age group differences across flood risk visualizations.

Variable	*H*-statistic	*df*	*p*-value (* statistical significance)
Young Adults			
Likely to Buy Property	4.184	4	0.382
Likely to Rent Property	1.262	4	0.868
Likely to Buy Flood Insurance	1.861	4	0.761
Likely to Take Preventive Actions	3.523	4	0.474
Middle-Aged Adults			
Likely to Buy Property	3.419	4	0.490
Likely to Rent Property	1.881	4	0.758
Likely to Buy Flood Insurance	2.492	4	0.646
Likely to Take Preventive Actions	5.400	4	0.249
Older Adults			
Likely to Buy Property	20.907	4	0.000*
Likely to Rent Property	15.806	4	0.003*
Likely to Buy Flood Insurance	8.326	4	0.080
Likely to Take Preventive Actions	5.122	4	0.275

3.4 Effect of Education Level

To examine the impact of education on behavioral responses to flood risk visuals, Kruskal-Wallis H-tests were conducted across three groups: 'Some college or less', 'Bachelor', and 'Graduate'. As shown in Table 10, statistically significant differences were observed across education levels for all four behavioral intent variables, i.e., likelihood to buy property ($H(2) = 95.446$, $p < 0.001$), rent property ($H(2) = 96.046$, $p < 0.001$), buy flood insurance ($H(2) = 30.685$, $p < 0.001$), and take preventive actions ($H(2) = 56.193$, $p < 0.001$). Dunn's post-hoc tests (Table 11) confirmed these differences were significant compared to participants with Bachelor or Graduate degrees. Participants with 'Some college or less' consistently reported significantly higher Likert scores (indicating lower willingness) compared to those in 'Bachelor' or 'Graduate' groups across all variables. These patterns suggest that individuals with lower levels of formal education expressed lower intent to purchase or rent property, buy insurance, or take preventive action in response to flood risk information, which may reflect heightened perceived risk. Kruskal-Wallis H-tests were run within each education group to assess whether visualization effects varied by education level. As shown in Table 12, significant differences in willingness to buy property were found only among participants with 'Some college or less' ($H(4) = 15.631$, $p = 0.004$). No significant differences were found within those in 'Bachelor' or 'Graduate' groups. Dunn's post-hoc tests revealed that the 'Some college or less' group were significantly less likely to buy property when shown Flood Images compared to Climate Central ($p = 0.037$) and NOAA ($p = 0.019$) maps. This pattern reflects the broader trend that photos prompt more cautious responses among those with lower education levels. One possible explanation is that complex visualizations may be harder to interpret, leading participants to rely more on vivid, real-world imagery. While speculative, this raises important considerations for equity and accessibility in risk communication.

Table 10: Kruskal-Wallis test comparing Likert-scale responses across different education levels.

Variable	***H*-statistic**	***df***	***p*-value (* statistical significance)**
Likely to Buy Property	95.446	2	<0.001*
Likely to Rent Property	96.046	2	<0.001*
Likely to Buy Flood Insurance	30.685	2	<0.001*
Likely to Take Preventive Actions	56.193	2	<0.001*

Table 11: Dunn's post-hoc test comparing pairwise differences in behavioral intent across education levels. Adjusted *p*-values are reported using Bonferroni correction. Only significant values are reported.

Pairwise difference	**Adjusted *p*-value (* statistical significance)**
Likely to buy property	
Some college or less – Bachelor	< 0.001*
Some college or less – Graduate	< 0.001*
Likely to rent property	
Some college or less – Bachelor	< 0.001*
Some college or less – Graduate	< 0.001*
Likely to buy flood insurance	
Some college or less – Bachelor	< 0.001*
Some college or less – Graduate	< 0.001*
Likely to take preventive actions	
Some college or less – Bachelor	< 0.001*
Some college or less – Graduate	< 0.001*

Table 12: Kruskal-Wallis H-test comparing education level differences across flood risk visualizations.

Variable	*H*-statistic	*df*	*p*-value (* statistical significance)
Some College or Less			
Likely to Buy Property	15.631	4	0.004*
Likely to Rent Property	5.292	4	0.259
Likely to Buy Flood Insurance	2.756	4	0.600
Likely to Take Preventive Actions	6.029	4	0.197
Bachelor			
Likely to Buy Property	2.066	4	0.724
Likely to Rent Property	2.147	4	0.709
Likely to Buy Flood Insurance	4.453	4	0.348
Likely to Take Preventive Actions	7.516	4	0.111
Graduate			
Likely to Buy Property	4.491	4	0.344
Likely to Rent Property	4.628	4	0.328
Likely to Buy Flood Insurance	6.263	4	0.180
Likely to Take Preventive Actions	7.650	4	0.105

4 DISCUSSION

This study investigated how the source and modality of flood risk visualization influence individuals' perceptions and behavioral intentions. Prior research has shown that risk communication format shapes how individuals interpret and respond to hazards. Ricard et al. (2017) found that indexical imagery, such as photographs of storm surge elicits stronger risk perceptions and behavioral intentions (e.g., evacuation) than abstract, map-based representations or no visuals. Similarly, our results show that participants who viewed photographic flood images reported significantly higher perceptions of flood severity and were less likely to consider buying or renting property in affected areas. This suggests that concrete visuals may activate affective heuristics, where individuals respond emotionally rather than analytically. These effects may vary across demographic groups due to differences in cognitive processing, familiarity with visual formats, and trust in visual information.

Modality effects were most pronounced among specific demographic groups. While overall gender differences in behavioral intent were not statistically significant, female participants showed more variation across visualization types, reporting lower intent to buy or rent property when shown photographic flood imagery. In contrast, male participants responded more consistently across all formats. This aligns with prior research indicating that women perceive higher risk and tend to be more risk-averse (Byrnes et al. 1999; Harris et al. 2006; Sattler et al. 2000), suggesting that visual modality may amplify gender-based differences in flood risk perception. Older adults also reported lower behavioral intent when viewing flood imagery, reflecting heightened perceived vulnerability to real-life visuals. This is consistent with prior research showing that older populations tend to exhibit greater caution in decision-making related to environmental hazards (Bodas et al. 2022; Peacock et al. 2005). Education further moderated responses: participants with 'Some college or less' consistently reported lower intent across all behavioral variables, especially in response to flood imagery. This may be due to lower cognitive load when interpreting technical content, greater familiarity with institutional maps, or stronger trust in authoritative sources, which could buffer emotional reactivity to flood imagery. Conversely, participants with less education may find abstract or technical visuals more cognitively demanding, making vivid imagery a more intuitive and emotionally salient cue for perceived risk.

Although we observed clear differences in perceived severity and behavioral intent, the results showed no significant variation in flood risk understanding or ease of interpretation across visual modalities. This finding is notable, as it suggests that while emotional salience and behavioral influence may vary by presentation style, participants' ability to interpret and understand the visual content (as measured through self-reported comprehension) remains stable across formats. One possible explanation is that most flood map designs included in the study were sufficiently legible and familiar, allowing participants to extract basic meaning regardless of stylistic differences.

While this study offers useful insights into how people interpret flood risk visuals, several limitations should be noted. The sample, drawn from Amazon Mechanical Turk is skewed towards younger, more male, and more educated than the general U.S. population, which may limit the generalizability of subgroup findings. Additionally, since behavioral intent was self-reported, it may not fully reflect real-world actions. Overall, the findings emphasize the importance of tailoring risk communication based not only on the type of information presented but also on audience characteristics.

5 CONCLUSION

This study underscores the importance of designing flood risk communication tools that are both visually effective and audience-aware. Participants exposed to photographic flood imagery reported lower willingness to engage in property transactions, especially among women, older adults, and individuals with lower education levels. These patterns varied by visual modality and highlight the importance of aligning risk communication with audience characteristics. Although participants reported similar levels of self-rated flood understanding and ease of interpretation across formats, their behavioral responses differed across visual types. This suggests that emotional and cognitive engagement with visual materials may differ by presentation style, even when basic comprehension remains stable.

These insights have important implications for practice. Public flood dashboards by local municipalities or federal agencies could better serve diverse users by combining map-based and photographic visuals. Emergency alerts may be more effective when they include localized flood imagery to boost urgency and relevance, especially for those less responsive to technical formats. Similarly, insurance outreach efforts could also benefit from real-world visuals to enhance engagement. It is essential that these systems remain accessible and adaptive to users with varying risk literacy and trust in authorities. However, while photos can increase salience, they may also provoke fear or overwhelm vulnerable groups. Therefore, emotionally charged visuals should be used carefully to balance urgency with trust.

ACKNOWLEDGMENTS

This research was supported by a seed grant from the Institute of Behavioral Science (IBS) at the University of Colorado Boulder.

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