The Pennsylvania State University
The Graduate School

EFFECTS OF STATIC AND INTERACTIVE SEA LEVEL RISE MAPS ON PERCEPTIONS OF TEMPORAL DISTANCE, RISK, AND SUPPORT FOR MITIGATION AND ADAPTATION STRATEGIES OF SEA LEVEL RISE

A Thesis in

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by

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ABSTRACT

This thesis investigates the impacts of static versus interactive maps on perceptions of risk and temporal distance associated with projected sea level rise (SLR) in Boston, MA. It also examines the influence of these map viewing environments on support for policies and actions aimed at mitigating and adapting to SLR and climate change. A survey of 404 participants, recruited via Amazon's Mechanical Turk platform, was conducted to assess changes in opinions and perceptions related to SLR and climate change before and after exposure to either static or interactive map viewing environments depicting SLR projections at Boston. The analysis indicates that there is no significant difference between the two environments in altering overall perceptions of risk or temporal distance related to SLR. However, specific demographic segments demonstrated a decrease in perceived risk of SLR following interaction with the interactive environment. Furthermore, engagement with the interactive environment was associated with increased support for policy measures to address SLR. These findings suggest that the effectiveness of map-based communication strategies may depend on the intended audience, emphasizing the need for tailored approaches in climate change communication.

Keywords: sea level rise, interactive maps, static maps, risk perception, temporal distance, climate change policy support

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Chapter 1
Introduction

The effects of climate change have the potential to inflict catastrophic and widespread consequences on our planet by the end of this century (IPCC, 2022). One such consequence, sea level rise (SLR), could affect the more than 600 million people living in coastal areas (UN, 2017). NASA (2022) has published projections of SLR under a range of greenhouse gas emission scenarios through the end of this century, extending from moderate to extreme, with the moderate scenario showing a one-foot increase and the extreme end projecting up to eight feet inundating our shorelines by 2100. Spreading awareness of the range of possible consequences of SLR to the general public could provide policy makers and leaders with the support they need to pass the vital legislation required to mitigate and adapt to some of the worst of these consequences (Houston, et al., 2017; Gifford et al., 2009). However, communicating these complex and threatening consequences to the public in a way that fosters understanding and inspires action to avoid worst case scenarios can be challenging.

Maps have been shown to be a powerful tool for communicating projected consequences of climate change. Retchless (2014) conducted a study comparing map and text-based representations of projected temperature increases in Pennsylvania (Figure **1-1**). Results from this study suggested that, compared to text-based representations alone, participants showed a greater understanding of these projected temperature increases when maps depicting the data were present. Fish (2020) reports that communication of climate change via maps is widespread, being distributed by both media outlets and governmental organizations to convey varying levels and types of information to audiences with varying degrees of scientific literacy. However, map-based communication does not necessarily translate into action. Since many of climate change's more severe anticipated consequences are projected to occur further out in the future (e.g., fifty to one hundred years from now), people may fall victim to a phenomenon called psychological distancing.

Liberman and Trope (2010) define psychological distancing as the tendency for people to think about events that will take place in the future or geographically distance locations differently than if those events were happening in the present moment or at that person's current physical location. This may, in turn, cause them to respond differently – or not all – and therefore fail to act in a way that may be necessary to avoid the worst projected consequences of climate change. Understanding how to communicate SLR – and climate change in general – through maps in a way that makes its consequences feel psychologically closer and prompts engagement and action from viewers (e.g., support for climate adaptation policy, behavioral and consumption change, etc.) may be crucial if we are to avoid these extreme scenarios.

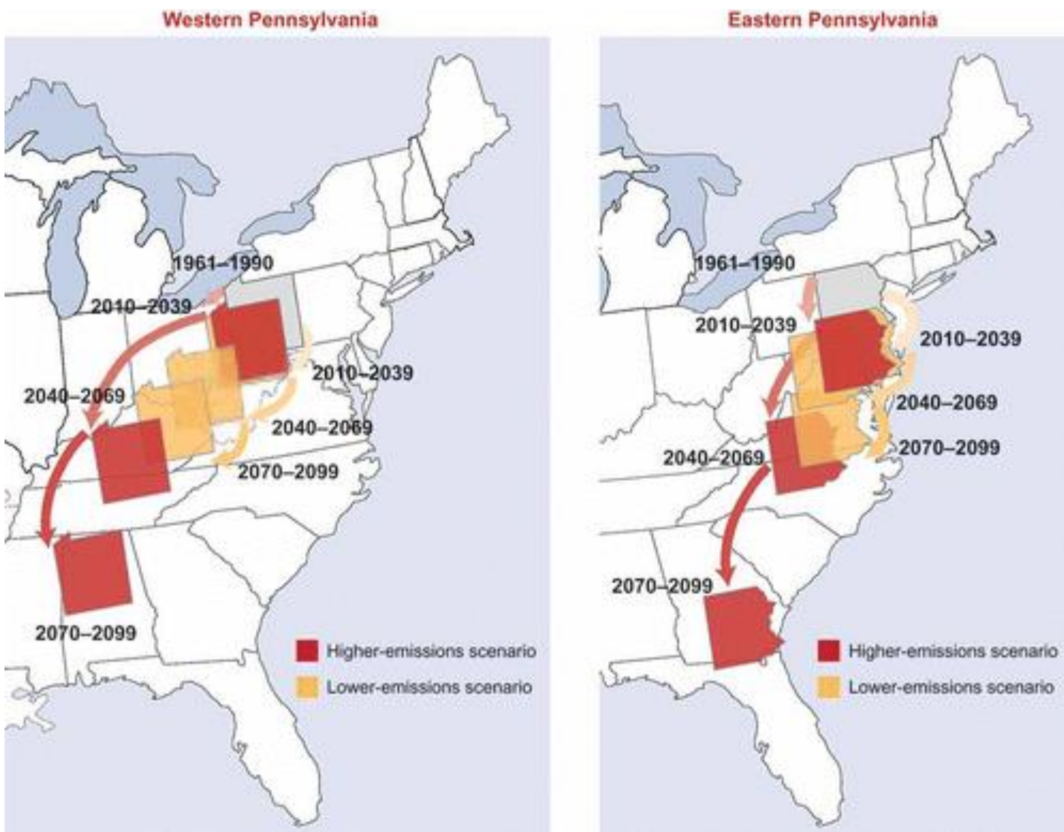

Figure **1-1**: Retchless's (2014) study exposed participants to projected temperature increases in Pennsylvania over the course of the 21st century. These changes were presented graphically by comparing future temperatures of eastern and western Pennsylvania to current temperatures in states further south.

This thesis attempts to address how different map viewing environments, namely, static and interactive, can be used to communicate the consequences of SLR and how perceptions of risk and temporal distance of SLR vary based on which environment is presenting the SLR information. It also explores how these two environments influence viewers' support for policies and individual action with the goal of SLR and climate change mitigation and adaptation. Understanding how these two map viewing environments differ in these regards will be beneficial to climate change communicators and policy makers seeking to foster a better understanding of the consequences of SLR among the general public and gain the support necessary to limit the negative effects of those consequences.

The remainder of this thesis is organized into five chapters. Chapter 2 reviews the current literature on perceptions of spatially and temporally distant events like climate change, perceptions of risk in relation to climate change, and how different map viewing environments may be used to influence those perceptions. Chapter 3 explores gaps in the current literature surrounding cartographic techniques and climate change communication; suggests four research questions to attempt to fill some of those gaps; explores research design methods; and introduces the static and interactive SLR map viewing environments and an accompanying survey to test those map viewing environments' effectiveness at communicating the risks and urgency of SLR. Chapter 4 examines the findings collected after that survey was administered to a pool of 404 participants recruited through Amazon Web Services' Mechanical Turk platform. Chapter 5 discusses the implications of those findings, as well as limitations to the methodology and materials used in this thesis, and explores possible areas for future research. Chapter 6 summarizes the goals and findings of this thesis.

Chapter 2
Literature Review

The following chapter reviews the current literature on how geographically wide-spread and temporally distant events like climate change are perceived in the general public's mind; how these perceptions inform risk and the role these risks play in whether action is taken to minimize them; and how different map viewing environments could be used to influence perceptions of risk of climate change and SLR to encourage support and action from their viewers. This literature review is divided into four sections. The first section examines psychological distance and the role it plays in perceptions of climate change. The second section discusses optimistic versus pessimistic outlooks of the future and how these outlooks encourage or discourage action. The third section reviews several studies on risk perception and how people act under certain flood risk scenarios. The fourth section examines interactive maps of SLR and their use and effectiveness in communicating SLR and climate change.

Psychological Distance

When one considers an event that is removed from their here and now, they may construe that event more abstractly than they would if it were more immediate to them (i.e., occurring to them in the present moment or at their physical location). This phenomenon, called psychological distancing, was defined by Liberman and Trope (2010) in their work on Construal Level Theory (CLT). They posit that the further something is from the here and now, the higher, or more abstract, one's level of understanding of it becomes. So, in the case of something like climate change, which may seem like a temporally and spatially distant event, one may be able to form an abstract idea of a warmer world or melting ice caps, but their conception of climate change will not be as tangible and concrete as the feeling of blistering temperatures of a heatwave or their waterlogged shoes as they evacuate their flooded home.

CLT splits psychological distance along four dimensions on which something can be removed from the here and now: spatially, temporally, socially, and hypothetically. Spatially refers to physical distance, or how far something is from one's physical location. Temporally refers to either forward or backward distance in time from one's present moment. Socially refers to the likeness of groups ("How similar (near) or different (distant) is this group of people from mine?"). Hypothetically refers to the likelihood that an event will occur, with higher likelihood events seeming nearer and lower likelihood events seeming more distant.

The temporal dimension is especially important in the role that it plays with climate change because time plays a major role in how people perceive anticipated changes to the planet, but also in the causes and effects of those changes. The EPA (2022) suggests that while many of the anthropogenic causes of climate change have been happening for the past 200-300 years, the consequences of those causes will occur gradually, over relatively longer periods of time. This lag in time between cause and effect can result in even more confusion in the way that humans understand and conceptualize these changes (Pahl, et al. 2014). To add to that, planning for such distant consequences is not necessarily in line with the way humans have evolved. Psychologically, human brains are understood to be programed for prioritization of short-term issues (e.g., making sure that there is food on the table or avoiding exposure to predators), while societally, humans tend to operate on time scales far shorter than those of the anticipated effects of climate change (e.g., 4-year election cycles, 5–20-year city planning schedules) (Pahl, et al., 2014).

Stemming from this tendency to better align with short-term cycles, a major problem that emerges from psychological distancing is that temporally distant events may not only be construed as more abstract, but they might also be discounted more than temporally nearer events (Liberman & Trope, 2003). In other words, something that is expected to occur in the more distant future is assigned less value than something that is expected to occur sooner. When it comes to climate change, this may mean that individuals do not care as much about the consequences that they see as far away, and therefore will not support or make the changes that are necessary to decrease the likelihood of those consequences occurring. Especially since those changes often require giving up positive aspects of their lives in the present (e.g., consume less, travel less, etc.).

Because of the role that psychological distance plays in perceptions of climate change, numerous studies have focused on how these perceptions of climate change's distance influence behavior and perceptions of the risks associated with the consequences of climate change (Leviston, et al., 2014; Schuldt et al., 2018; Wang et al., 2019; Brügger et al., 2015; Chu & Yang, 2018; Brügger, 2020; Retchless, 2018; McDonald, et al. 2015; Spence et al., 2011; Pahl et al., 2014; Jones et al., 2016; Rickard et al., 2016). Since psychologically distant phenomena tend to be perceived as more abstract and are more discounted than psychologically proximal phenomena, some have suggested that presenting the consequences of climate change as psychologically closer to the intended audience will be more effective in prompting action against climate change from that audience (Jones et al., 2016; Rickard et al., 2016). Several studies have attempted to measure this effect, with varying results. Schuldt et al (2018) manipulated US participants' perceptions of proximity to the Maldives, an archipelago in the Indian Ocean, by asking them to draw a line connecting Ithaca, New York (the location of the study) to the Maldives, on either a large or small map (i.e., taking up more or less space on their computer screen). This task resulted in participants drawing either a longer or shorter line connecting the two locations on their screen, depending on which map they were assigned (Figure **2-1**). Previous studies have suggested that plotting points of different distances on a Cartesian plane could prime participants for the concept of spatial distance (Williams & Bargh, 2008). After completing the task, participants watched a short video outlining the effects of climate change on the Maldives. Results suggest that participants who were assigned smaller maps – and therefore drew shorter lines, presumably decreasing their psychological (spatial) distance from the Maldives – described the climate change video that they viewed in more concrete and thorough terms, whereas those who were given larger maps – and presumably viewed the Maldives as more spatially distant – described the video in more abstract terms. However, despite this decrease in psychological distance, researchers found no impact on the participants' support for climate change policy.

Figure **2-1**: Schuldt et al. (2018) manipulated participants' perception of the distance between their location (Ithica, NY) with the Maldives by having them draw a line connecting the two locations on a map, using different map sizes, and therefore different line lengths, to test how these perceptions affected how they construed ideas about climate change.

Brügger et al. (2015) and Brügger (2020) insist that framing climate change as psychologically near will not necessarily result in the desired outcomes that others have claimed (e.g., increased support for climate mitigation and adaptation policy), with the latter insisting that CLT has largely been misused and misunderstood in its applications to climate change communication for three reasons.
First, researchers often link psychological distance to personal relevance, with the assumption that decreasing psychological distance will make an event more relevant to the observer and therefore make them more likely to act on it. Brügger, however, claims that CLT describes psychological distance and personal relevance as independent from one another, and therefore altering psychological distance cannot predict changes in personal relevance. Second, researchers often assume stability in participants' perceptions of psychological distance, whereas CLT asserts that the psychological distance and abstraction of an object can change. Third, the assumption that making events psychologically close and

more concrete will permanently alter a person's views of the event is not in line with CLT's transient nature. Brügger suggests researchers use alternate frameworks for these types of studies, such as risk processing models, mental models, Bayesian updating, or conceptual change.

Others have identified the need to promote wider, more global views of climate change in addition to local and tangible imagery (Spence et al., 2012; McDonald et al., 2015). However, ideological divides among viewers result in varying outcomes when information is presented in this way and may require fine tuning according to the audience. Hart and Nisbet (2011) explored social distance's ("how similar or different are this group to my group?") effects on perceptions of climate change among individuals with opposing political ideologies by exposing participants in New York to climate change-related health stories about victims both socially near (New York) and far (Georgia, USA and France) from those participants. They found that participants who identified as Republican were more likely to support climate change policies when exposed to stories about victims socially nearer (i.e., similar) to them, whereas people who identified as Democrat exhibited the opposite preference.

When looking at spatial distance, promoting wider, global perceptions of climate change results in some surprising outcomes. Retchless (2018) examined the effects of spatial distance on risk perceptions of climate change through interactive SLR maps by showing these maps to participants both spatially near and far from the location represented on the maps, Sarasota, Florida. While individuals who lived closer to the area on the map (Sarasota, Florida) reported higher overall risk perceptions of SLR, individuals who were further away, and expected to be relatively unaffected by SLR (State College, Pennsylvania), showed a larger pre- to post- increase in risk perception after viewing the map. This finding can possibly be attributed to another phenomenon that interacts with distance and perceptions of climate change: spatial optimism bias. This bias is the tendency to view one's own location as being less likely to experience negative effects than other, more distant locations. This may further interfere with the assumption that exposing people to psychologically closer depictions of climate change will result in increased support for policies and actions designed to mitigate and adapt to climate change.

Optimism, Pessimism, and Climate Change

Optimism and pessimism seem to play different roles in how climate change is perceived, depending on the type of psychological distance in question. Although optimism may seem like the ideal attitude towards any given situation, it might not lead to the type of support and action required in the face of climate change. Outlooks also vary depending on whether one is thinking about their own future, or the future of the world as a whole. McElwee and Brittain (2009) found that college students in New Jersey were more optimistic about their own future than that of the world, possibly due to a feeling of control over their own choices and outcomes, but not of those globally. When they factored in attitudes towards climate change and environmental concern, they found that personal optimism had no correlation to these attitudes. However, world optimism was negatively correlated with them (i.e., high levels of global optimism were associated with lower levels of environmental concern, and vice versa). This presents another difficulty in addressing climate change. On the one hand, if one is too pessimistic about the future and concerned about the environment, they may not feel that it is in their control to change anything about it. On the other hand, if one is too optimistic about the future, then they may see no need to do anything to improve it (McElwee & Brittain, 2009). In either case, these individuals would have little impetus to act. Striking a balance between optimism and pessimism seems to be key here.

Spatial optimism about climate change was found to be prevalent among individuals across a range of countries, even those countries that are objectively expected to be worse off than others, in a study from Gifford et al. (2009). Participants rated their local environmental conditions as better than national, and better yet than global. Temporally, however, they were far less optimistic. Respondents from nearly all nations in the study were pessimistic about the future on all levels of spatial proximity, maintaining the attitude that "things will get worse with time." While this seemingly goes against the idea that people discount and worry less about distant problems, the authors suggest that perhaps participants are simply aware of the dangers that the world faces and expect them to occur. Another possibility is that since the problem is so distant, and therefore less of a threat to them in the here and now, they may feel free to express pessimistic opinions "contrary to the typically pervasive optimism bias," (Gifford et al., 2009, p. 7).

Risk Perception and Action in the Face of Climate Change

While simply understanding the consequences of climate change is important, for people to act it is also important for them to understand how those consequences will impact them. However, increasing risk perceptions, and the resulting actions taken because of those perceptions, is not always as straightforward as simply providing individuals with information about the potential risks that they face. In a study on flood risk perception and subsequent action, Lo (2013) found no relationship between an individual's perception of flood risk and their purchasing of flood insurance – an action that might be expected in the face of such risk. There was, however, a third variable present – perception of social norms – that connected the two. When individuals saw that others around them perceived flooding to pose a high risk to them and subsequently changed their behavior because of that (i.e., purchased flood insurance), the individual was more likely to do the same. This may imply that greater awareness of these risks among the population as a whole is more effective than individual targeting for risk awareness. It could also mean that the decision to act produces a domino effect, and as more people act, more will follow.

These findings are consistent with theories of critical psychology and the role that it plays in climate change, specifically the factors and complexity that go into perceptions and behavior change (e.g., social context and interaction) (Adams, 2021). In a study on behavioral biases observed during the COVID-19 pandemic, and implications that they may have for climate change mitigation and adaptation, Botzen et al. (2021) discuss the herding bias, which describes how individual choices are influenced by the behavior of others around them. When communities are focused on addressing the consequences of climate change, individuals within those communities may be more likely to act as well. On the flip side, if an individuals' neighbors are not acting or are actively disregarding information about climate change, the individual will likely do the same. Exposure to climate change information alone may not be sufficient to change individual behavior to mitigate the effects of climate change.

In another study on perceptions of flood risk and resulting behavior, Horney et al. (2010) tested whether awareness of flood risk could predict whether or not an individual had evacuated their home during the 2003 Hurricane Isabel in North Carolina. Using Federal Emergency Management Agency flood maps as an indicator of a property's risk to being inundated by hurricane flood waters, the authors found that more than half of the participants living in the riskiest area characterized their flood risk as less than what it actually was according to those maps. They also found that those who did perceive their risk to be medium to high were no more likely to have evacuated during Hurricane Isabel or to plan to evacuate from future hurricanes than those who perceived their risk to be low. Nevertheless, the authors suggested spreading further awareness of flood risk, in part through the distribution of updated flood hazard maps (Horney et al., 2010).

Interactive Maps for Communicating SLR

Interactive maps and visualizations have been shown to spread climate change awareness and promote engagement (Retchless, 2014; Retchless, 2018; Hutton & Allen, 2022; Stephens & Richards, 2020). Retchless (2014b) argues that online interactive maps are powerful tools for depicting SLR, citing two popular interactive SLR maps, NOAA's *Sea Level Rise and Coastal Flooding Impacts Viewer* (https://coast.noaa.gov/slr/) and Climate Central's *Surging Seas* (https://ss2.climatecentral.org/), as examples. Retchless claims that three features of these interactive maps are effective in limiting an individual's discounting of the consequences of SLR. First, these maps make SLR local to a wider range of viewers by allowing users to easily zoom to various scales representing geographic extents like neighborhoods or blocks, rather than only showing entire cities, states, or countries, which may be more common on a widely distributed static SLR map. Second, interactive maps make SLR tangible by including interactive elements such as landmark popups to show not just where SLR will have an effect, but what personally relevant places might be affected. And third, interactive maps make SLR personal by providing pan and zoom capabilities that allow users to explore areas that they know and live in. Stephens et al., (2016, p. 249) argue that interactive SLR maps allow scientists to communicate complex information to their audiences and that these visualizations "can enhance mental model precision, complexity, and function," allowing viewers to gain a deeper understanding of SLR.

Hutton and Allen (2022) tested the effectiveness of interactive SLR maps that depicted how certain areas would be affected by SLR in 2050, 2080, and 2100 in Norfolk, Virginia (Figure **2-2**). They compared the effectiveness of these interactive maps to static photographs depicting blue lines spray painted on land surfaces where high tide is projected to reach in those same time periods (Figure **2-3**). Participants favored the maps over the photographs, claiming that maps were more informative, though perhaps less convincing. However, despite the information provided by the interactive SLR maps, most of the participants reported that their likelihood of taking action to mitigate or adapt to climate change did not change after viewing the maps.

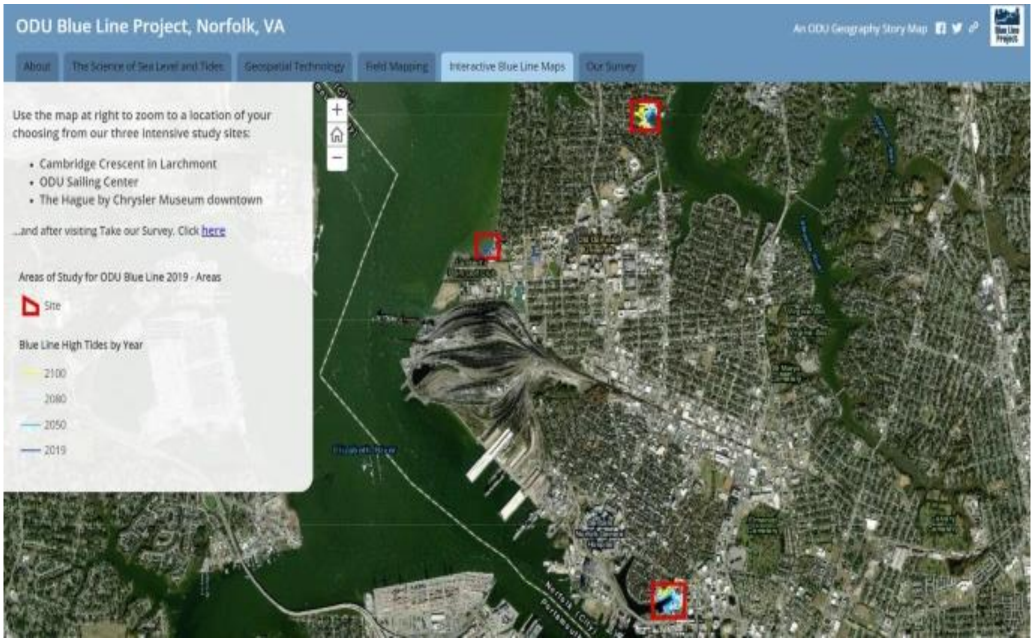

Figure **2-2:** Interactive SLR map showing projected SLR at three study locations (represented by red rectangles) in Norfolk, Virginia for 2050, 2080, and 2100. The three study locations highlighted in red are the same locations where blue lines were painted to depict SLR, shown in Figure **2-3**. Source: Hutton and Allen (2022).

Figure **2-3**: Hutton and Allen's (2022) real-world depiction of SLR's potential impact, painted on a boat launch ramp in Norfolk, Virginia.

Conclusion

This chapter reviewed the current literature on how psychologically distant events like climate change are perceived, the role that optimism and pessimism play in perceptions and action on climate change, how perceived risk translates into action with regard to climate change events, and how maps are used to communicate the risks and projected consequences of climate change. While the research presented on the use of maps to communicate the consequences of climate change provide a solid foundation, several gaps were evident. The following chapter will examine those gaps, pose several research questions to help fill those gaps, and present the methodology required to answer those questions.

Chapter 3
Methodology

The literature review presented in Chapter 2 highlighted important aspects of current research regarding the role that psychological distance and maps play with respect to perceptions and understanding of the risks and consequences of climate change and SLR. However, two important aspects of this body of research are missing. First, while interactive SLR maps have been shown to be a popular tool for depicting SLR and climate change, little evidence has demonstrated their effectiveness at increasing perceptions of risk, decreasing perceptions of temporal distance, or increasing support for policies and individual action to mitigate and adapt to SLR and climate change. Static maps have received even less attention in this realm. Second, no studies have been found that compared interactive and static maps against each other on these parameters. In fact, Retchless (2018) suggested that a study be performed on the differences between static and interactive maps in communicating the risks of SLR.

Researchers have cited the advantages of interactive maps to convey the projected consequences of SLR to the general public (Retchless, 2014; Monmonier, 2008, Stephens et al., 2016), but have not quantified those advantages over static maps, at least not with respect to their effects on perceptions of risk and temporal distance of SLR, or on support for policies and individual actions to mitigate and adapt to SLR and climate change. Thus, understanding how these different map viewing environments affect perceptions of risk and temporal distance of SLR, as well as support for policies and actions to mitigate and adapt to SLR will be important for communicating SLR to the public and, hopefully, enacting the changes required to avoid the worst of climate change’s consequences. The importance of understanding these effects serves as the foundation for developing the following research questions (Table **3-1**).

Table **3-1**: Research questions guiding this thesis

Research Question 1 (RQ1)	Do static and interactive maps differ in communicating the risks of SLR?
Research Question 2 (RQ2)	Do static and interactive maps differ in decreasing perceptions of temporal distance of SLR?
Research Question 3 (RQ3)	Do static and interactive maps differ in increasing support for policies and individual action to mitigate and adapt to SLR and climate change?
Research Question 4 (RQ4)	What aspects or qualities of static or interactive maps help make SLR depictions feel temporally closer and/or prompt engagement with climate change?

Relevance and Importance of the Research

This research aims to contribute to the understanding of how different map viewing environments, namely static and interactive, can influence people's perceptions of risk and temporal distance of SLR, as well as their level of participatory support and action for addressing climate change and its consequences. Several studies addressing strategies for climate change communication – and many of the public-facing communication tools – have used interactive maps to disseminate information on the consequences of climate change, mainly focusing on SLR (Hutton & Allen, 2022; Stephens & Richards, 2020; Stephens, et al., 2016; Retchless, 2018; Retchless, 2014). These studies generally regard interactive maps as being more effective than static maps at conveying climate change and SLR information. However, they failed to thoroughly address tradeoffs between the two map viewing environments. Interactive maps may have three limitations when compared to static maps. First, interactive maps require technology (e.g., a mobile device or computer and in many cases, an internet connection) to be accessed and viewed, whereas static maps can be printed and posted in public settings. Second, while static maps present all of their information simultaneously, interactive maps require interaction from the user and may require instructions and guidance to navigate the interface to reveal information contained within the database. Third, compared to static maps, interactive maps can be more costly, complicated, and time-consuming to create. However, the relative ease of creating and distributing static maps may not make up for the lost benefits that come from interactivity in communicating SLR risk through interactive map viewing environments.

By exploring the differences between static and interactive map viewing environments of SLR, effective strategies for communicating the risks and temporal distance of SLR to the public will be identified. This research will have implications for other researchers, policymakers, educators, and climate change communicators regarding their decision on how best to use maps to represent SLR to promote action by their community and beyond.

The premise of this thesis follows the lead of Retchless's (2018) study on risk perceptions of SLR through interactive maps with regards to spatial distance. Here, Retchless used a pretest-posttest approach to gauge the attitudes and perceptions of risks of SLR and climate change among university students both before and after being exposed to SLR maps of the Sarasota, Florida area. Houston et al. (2017) used a similar approach in examining the role that hazard maps play in spreading awareness of flooding. In addition, Hutton and Allen (2022) employed this method while looking into the differences between interactive SLR maps and static photographs of SLR's potential impacts. The pretest-posttest method is used in this thesis to gauge the impacts that viewing the interactive and static SLR map viewing environments have on viewers' perceptions of risk and temporal distance of SLR, as well as their likelihood of supporting policies and enacting individual actions to mitigate and adapt to climate change and SLR.

Research Design

To answer the four research questions posed at the beginning of this chapter (Table **3-1**), an online survey was developed and administered to participants to study their perceptions of risk and temporal distance of SLR. In this survey, a pretest-posttest method was used by asking participants a series of questions both before and after they viewed maps of projected SLR in Boston, Massachusetts. The location of this study was chosen for three reasons. First, being a coastal city, Boston is expected to experience the consequences of SLR in the coming decades and will therefore require support for mitigation and adaptation strategies to limit the effects of those consequences. Second, Boston provides open access to up-to-date data on SLR projections in and around the city. Third, Boston presently has a robust Climate Action Plan in place, and this research could be beneficial to the communication strategies used to advance the goals of that plan.

The survey includes a series of questions about the participants' perceptions of the risks and temporal distance of SLR, and of their level of support for solutions widely considered to help mitigate and/or adapt to the effects of SLR and climate change. Participants responded to the online survey at the start of the task to gauge their preexisting views and beliefs and perceptions of climate change and SLR. Once participants responded to the survey questions, they were randomly assigned to view either a static map viewing environment (a collection of six static maps) or an interactive map viewing environment showing projected SLR in Boston, with projections of water levels in 2030, 2050, and 2070. After viewing the environments, participants were asked to respond to the same questions as those which were asked prior to viewing the environments.

Statistical analyses were then used to compare the participants' responses to understand the effectiveness of the static vs. interactive map viewing environments at altering those responses. Analyzing the responses focused on whether the map viewing environments played a role in altering perceptions of temporal distance and risk associated with SLR, as well as whether or not the map viewing environments had any effect on participants' willingness to support policies and actions to mitigate and adapt to SLR and climate change. Qualitative methods were selected to analyze open-ended responses to learn what users understood climate change to be and which aspects of the maps, if any, helped to convey

SLR information to them. A quantitative assessment of responses was also applied to determine if differences in responses to select questions between the two environments were statistically significant.

Methods and Data Sources

All SLR data for the maps created in this study come from Boston's open data hub, Analyze Boston. These data include a shapefile of Boston's city boundary and three polygon shapefiles showing the area of Boston that is expected to be inundated at hightide at three points in the future: 2030 (9-inch increase), 2050 (21-inch increase), and 2070 (36-inch increase). These estimated increases were calculated by the Massachusetts Department of Transportation Federal Highway Administration to represent moderate to extreme scenarios based on current greenhouse gas emission trajectories. The water inundation polygons initially included all water features surrounding Boston, including areas that are currently inundated, such as the Boston Harbor and the Charles River. Figure **3-1** shows an example of the 2030 (9-inch increase) polygon in its unedited form.

Figure **3-1**: 2030 (9-inch increase) SLR shapefile projection of Boston shows the areas of the city that will be affected by SLR (in blue) in 2030. This polygon also includes all current water features, such as rivers and ocean, and requires processing to be included in the maps.

To highlight only areas of the city that are not currently inundated on the maps, each shapefile was clipped to the current city boundary of Boston. The results of this process on the 2030 (9-inch increase) shapefile are depicted in Figure **3-2**.

Figure **3-2**: 2030 (9-inch increase) SLR shapefile projection of Boston after being clipped to the Boston boundary shapefile. Blue areas show locations that are not currently underwater but are projected to be in 2030.

Map Design

ArcGIS Pro was used to generate the maps depicted in the static map viewing environments, while ArcGIS Online and ArcGIS Instant Apps were used to create the interactive map viewing environment. Six static maps illustrate SLR scenarios for 2030, 2050, and 2070. Figure **3-3** depicts an example of the static map that illustrates the 2070 (36-inch increase) SLR scenario in Boston. Three of the six static maps incorporate a grayscale basemap (one map for each of the three SLR scenarios), while three additional maps were created using a satellite basemap (one map for each of the three SLR scenarios). Figure **3-4** illustrates an example of the SLR scenario for 2070 (36-inch increase) with a satellite basemap. Each map shows projected SLR for the three years shaded in blue. This varied basemap design allows participants to investigate the areas that will be affected by each SLR scenario in more detail (e.g., to see which types of features will be affected, such as buildings, highways, parking lots, etc.).

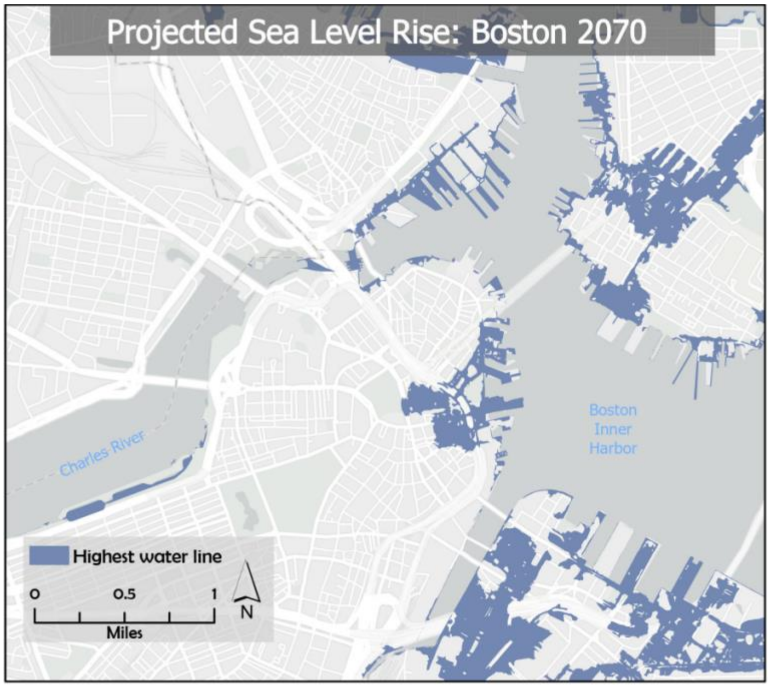

Figure **3-3**: Static map depicting projected SLR in Boston in 2070 with grayscale basemap.

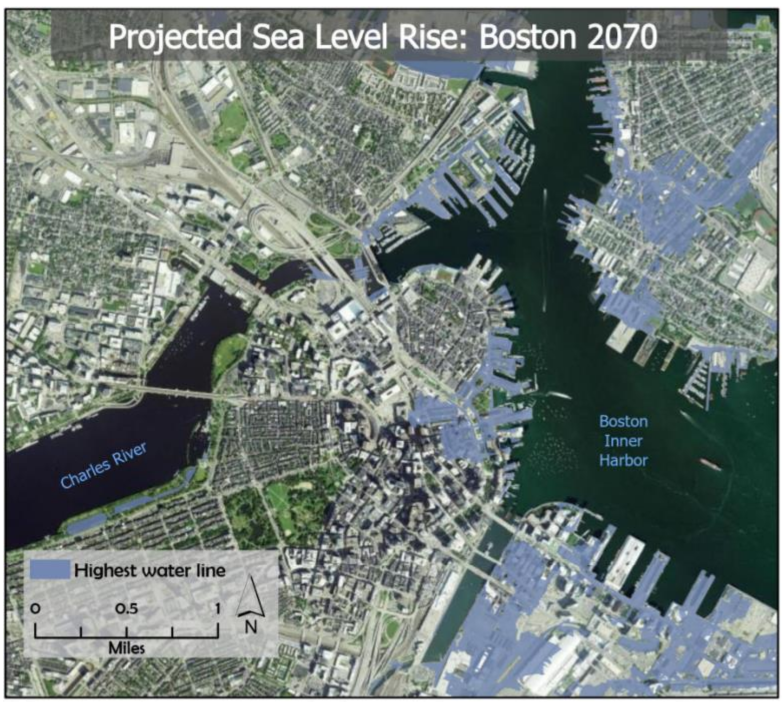

Figure **3-4**: Static map depicting projected SLR in Boston in 2070 with satellite basemap.

The interactive map viewing environment (Figure **3-5**) includes the same three projected SLR layers used in the static environment (2030, 2050, and 2070). Participants have the ability to toggle between these layers to view the different SLR scenarios. As with the static map viewing environment, projected SLR is displayed in blue on the interactive map viewing environment. Participants also have the ability to toggle between the grayscale basemap and the satellite basemap. These basemap options, coupled with the three SLR water level layers, allow participants to combine layers in six different ways, effectively showing them the same information portrayed in the six static maps (grayscale with 2030 SLR, grayscale with 2050 SLR, grayscale with 2070 SLR, satellite with 2030 SLR, satellite with 2050 SLR, satellite with 2070 SLR) used in the static map viewing environment. However, the interactive map viewing environment includes increased interactivity options, such as pan and zoom, to further encourage investigation into the areas projected to be affected by SLR. Because the interactive map viewing environment requires more action from the participants, an instruction screen is displayed upon opening the map.

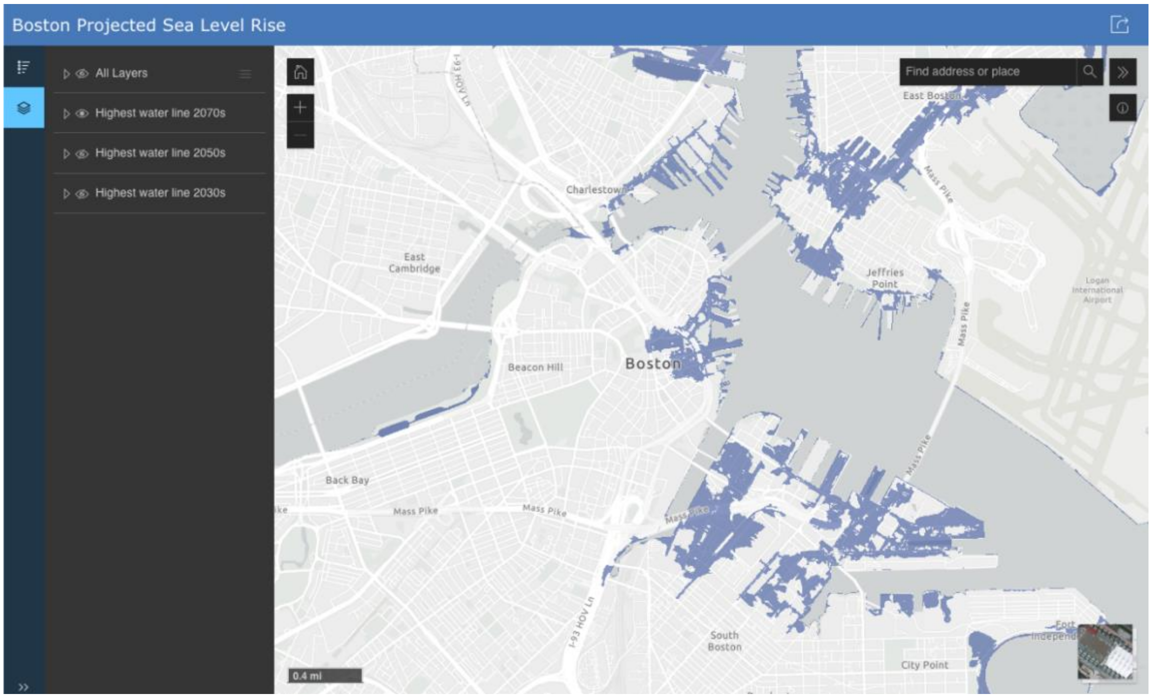

Figure **3-5**: The interactive map viewing environment depicting projected SLR in Boston in 2030, 2050, and 2070. The current map shows SLR projections for 2070 with the grayscale basemap.

The map designs were kept simple, showing only SLR projections on top of a basemap. Although additional features such as popups, levels of uncertainty in the data, or additional data on further effects of SLR, such as storm surges, might make this interactive map viewing environment more effective at conveying the consequences of SLR to participants, these features were not included. Since the goal of this study is to test the difference between static and interactive map viewing environments on various perceptions of SLR, all map design options within both environments were kept as similar as possible (compare the static and interactive map designs for 2070 SLR on a grayscale basemap shown in Figure **3-3** and Figure **3-4**, respectively).

Survey Protocol Design and Development

The survey was be created using Qualtrics XM, a web-based data collection platform for survey design, development, distribution, data collection and analysis. The survey took place in a web-based environment where questions were displayed one at a time in the participant's web browser. All questions required a response from the participant in order for them to proceed to the next question. Participants could not return to previous questions after advancing. The purpose of these constraints was to prevent participants from revising their responses after being exposed to new information.

Participants were recruited through Amazon Web Services' Mechanical Turk (MTurk) platform, an online marketplace where users (requesters) recruit other users (workers) to complete tasks (Human Intelligence Tasks, or HITs), such as audio transcription, document translation, or, in this case, surveys. MTurk is a widely used tool in academic research and provides researchers with an extensive pool of participants and the ability to conduct research faster and for cheaper than traditional participant recruitment methods (Litman & Robinson, 2021, p. 1). Another benefit of MTurk is that the pool of potential participants is generally more representative of the general population than the typical pool of undergraduate students, potentially leading to a reduction in bias in responses (Buhrmester et al., 2011).

MTurk workers are paid a rate set by the requester to complete HITs. After a worker completes a HIT, the requester has the ability to review the quality of the work to decide whether or not to accept it, and therefore whether or not to pay the worker (Litman & Robinson, 2021, p. 28). MTurk keeps track of how frequently a worker's HITs are accepted or rejected and assigns them a rating based on that frequency. MTurk allows requesters to set a rating threshold on who can respond to their requests, potentially allowing for higher quality responses.

Two surveys were administered to participants at random, one employing the static map viewing environment and one the interactive map viewing environment to convey SLR information. A preliminary test run of the survey suggested an average completion time of just over six minutes. With this average completion time in mind, payment to complete the survey was set to $1.50, or an hourly rate of $15, which lies on the higher end of minimum wages by state in the US. The survey employing the static map viewing environment consisted of 28 questions, while the survey with the interactive map viewing environment included those same 28 questions, plus one additional question to determine how participants interacted with the interactive environment, in lieu of eye- or mouse-tracking software. The questions included 5 open-ended (plus one additional for those who viewed the interactive environment), 4 text box (prompting participants to input a number), 6 multiple choice, and 13 Likert scale. All questions are included in Appendix A in the order that they were be presented to participants of the study.

Mixed Methods Research

These surveys use a combination of questions that are designed to elicit both qualitative and quantitative data, known as mixed methods, to understand the effect that these static and interactive map viewing environments have on perceptions of risk and temporal distance of SLR, as well as on support for policies and individual actions to mitigate and adapt to SLR and climate change. In their review on the state of mixed methods research, Doyle et al. (2016) argue that while mixed methods studies are not inherently better than either quantitative or qualitative alone, certain situations provide justification for their use. Two of the rationales that they list for using mixed methods apply here: triangulation and completeness.

Triangulation refers to the use of qualitative and quantitative methods to mutually corroborate findings, generally pertaining to a single research question. In this case, triangulation is useful in answering RQ2: Do static and interactive maps differ in communicating the risks of SLR? To answer this question, participants were asked qualitative questions about perceptions of distance, such as questions 14 and 22 (Appendix A) ("How much risk do you believe sea level rise poses to humanity during this century? (0 = no risk at all, 4 = extreme risk)"), as well as quantitative, such as questions 15, 18, 23, and 26 (Appendix A) ("Approximately how much time do you believe you have before sea level rise begins to affect your daily life? Enter an approximate number of years." and "How many years do you expect it to take before the water level reaches the green dot?"). These responses allow for perceptions of the temporal distance of SLR to be both quantified as a number of years and expressed as a level of risk that they do or do not expect in their lifetime.

Completeness refers to the use of qualitative and quantitative methods to provide a more comprehensive account of what is being studied. When looking at how static versus interactive map viewing environments affect perceptions of risk and temporal distance of SLR, a comprehensive response containing both quantitative data about how these maps affect these perceptions numerically, such as in questions 15, 22, 25, and 28 (Appendix A), as well as how they affect their expectations, plans for action, and understanding of SLR and climate change qualitatively, such as in questions 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 23, 24, 26 and 27, are beneficial to understanding which viewing environment has more of an effect on these perceptions.

Question Creation: Original and Sourcing

This section discusses the development of the questions for the online survey. The questions used in this survey are a combination of original questions and questions sourced from previous works. Robinson and Leonard (2018, p. 79-80) suggest using or adapting existing questions when those questions are accessible and available and when the current research will benefit from previously conducted validation and reliability. Several questions in this survey were adapted from two sources. Questions 14 and 24 were sourced from Retchless's (2018) work, which looked at how interactive map viewing environments and spatial distance affect perceptions of risk of SLR and climate change. Questions 9 through 12 were sourced from Chryst et al.'s (2022) Six Americas Super Short Survey (SASSY), which itself was adapted from Leiserowitz et al.'s (2022) Global Warming's Six Americas classification system. This classification system was also used in Retchless's (2018) study. The remaining questions are original, with inspiration from previous studies discussed in the literature review in Chapter 2 and methodology developed from suggestions in Robinson and Leonard's (2018) *Designing Quality Survey Questions*.

Question Types

Three question types are used in this survey: open-ended, multiple choice, and Likert scale. Open-ended questions are used to capture a wider range of ideas and interpretations that participants have on SLR and climate change. Multiple choice and Likert scale questions are used to offer participants a finite range of responses that allowed for comparison between participants and map viewing environments.

Original Questions

Open-ended

Questions 8, 13, 17, 20, 22.5 (interactive only), and 23 are the only longer form open-ended questions on this survey (15, 22, 25, and 28 are technically open-ended, but they only ask for a response of a single number and are referred to as 'Text box' question types in Appendix A), each with a 500-character limit to keep participants' responses concise. While open-ended questions can be risky and result in nonresponses or incomplete surveys, Robinson and Leonard (2018) note their usefulness in capturing "rich, detailed, and nuanced understanding of respondents' thoughts, feelings, opinions, attitudes, or experiences," (2018, p. 94). They also suggest several methods for ensuring that these types of questions receive responses, including letting participants know that grammar or spelling will not be of concern and communicating expectations, such as the level of detail expected in their answers. Asking for 'a few words or sentences' should satisfy those suggestions, allowing participants to freely write as much (up to 500 characters) or as little as they would like, and whatever comes to their mind without the need for much structure.

Question 22.5 was only asked to participants who viewed the interactive map viewing environment. The purpose of this question is to understand how participants interacted with the environment in lieu of any tracking software.

Question 23 is used to determine which aspects of the two mapping environments were effective at communicating the risks and temporal distance of SLR and to help understand how the two map viewing environments differ in communicating this information.

Questions 8 is used gain an initial understanding of what comes to each participants' mind when they think of climate change, before diving into more pointed questions about some of the consequences of climate change, namely SLR, and how they think these consequences will affect them in the future.

Questions 15 and 25 provided participants with the opportunity to enter a numerical estimate on how long before they expect to experience the effects of SLR in their daily life. These questions allow participants give a quantitative estimate to support their responses to questions 14 and 24 on their perceptions of the risks of SLR during this century and avoid the need to supply participants with a long list of multiple-choice options.

Questions 22 and 28 are meant to test the two map viewing environments' ability to convey the threat of SLR and the temporal distance of that threat. Participants were shown a map of Boston with current sea levels and a green dot placed on the map, within the city. They were asked to enter an estimate, in years, for when they expect water levels to reach that point due to SLR.

Likert Scale

Question 6 is used to gauge participants' emotional connection to Boston. Responses to this question, along with question 5, which asks about participants physical distance from Boston, are used to account for any spatial or psychological 'closeness' that participants have to Boston. As mentioned in the literature review in Chapter 2, one suggestion for prompting engagement and action on climate change is to present its consequences as being psychologically near (Jones et al., 2016; Rickard et al., 2016). Comparing responses from participants who are close to Boston, whether spatially or emotionally, to those who are more distant are used to test that suggestion.

Questions 16, 18, 19, 21, 26, and 27 are intended to gauge participants' level of support for policies and individual action to mitigate and adapt to SLR. The response options for these questions fall on a bipolar Likert rating scale of six options ranging from 'Very likely' to 'Very unlikely'. Robinson and Leonard (2018) note a trade-off between granularity and confusion when deciding on the number of options to include. Too many options may make it more difficult for a participant to decide where they stand, but too few may lump too many participants into too large of a group. They suggest that anywhere from 4 to 7 options is generally recommended for optimal results (Robinson & Leonard, 2018, p. 107). The choice to use an even number of options, and thus leaving out a midpoint ('Neither agree nor disagree'), is intended to illicit a definitive response from each participant for more accurate analysis. The inclusion of a midpoint can sometimes lead to a ‘face-saving don’t know’, rather than a true neutral opinion, so forcing a choice should help to avoid such scenarios (Robinson & Leonard, 2018, p. 108).

Multiple Choice

Questions 1 through 4 are demographic questions that are used to group participants for analysis. These questions allow for calculating differences in responses between groups, which could be useful for targeted communication. Gender, education level, and age are all considered commonly used demographic variables by Robinson and Leonard (2018, p. 141). Political preference is not, however, it is included in this survey for two reasons. One, there tends to be a political divide in views on climate change, with Democrats generally believing that climate change is happening and is caused by human activity, and that action needs to be taken to mitigate its effects, and Republicans less likely to hold such views (Kennedy & Johnson, 2020; Druckman & McGrath, 2019). Two, findings from Hart and Nisbet's (2011) study on climate change and psychological (social) distance suggested that Democrats and Republicans respond differently to communication efforts. These views are tested through the lens of temporal distance in this thesis.

Because of the sensitive nature of some of these questions, Robinson and Leonard (2018, 148) suggest that a ‘Prefer not to answer’ option be included. While this may make analysis by demographics more difficult, it hopefully encouraged more participants to complete the survey. They also suggest that if a self-identify text entry box is included on questions about gender, it should be accompanied by the phrase ‘Prefer to describe’, rather than ‘other, which can have negative connotations. These suggestions were applied to the demographic questions in this survey.

Question 5 is intended to provide a general understanding of the spatial distribution of participants relative to the study location. Because this sample of participants was drawn from the entire United States, knowing each participants relative proximity to Boston allows for accounting of the effects of spatial distancing in the responses. Retchless (2018) found that greater distance from the location of SLR maps resulted in a larger effect on perceptions of risk of SLR after viewing the maps. Since this thesis is focuses on temporal distance, rather than spatial distance, the effect of the spatial variable should be accounted for in the analysis. The three answer choices are kept simple to avoid confusion among participants. Any participant within 10 miles of the city is assumed to be living in the city. Participants within 100 miles are living within the New England region and are still relatively near to Boston. Participants beyond 100 miles are considered outside of both Boston and New England, living far outside of the study area.

Question 7 is intended to understand how perceptions of risk and temporal distance of SLR vary among those who do or do not live near the ocean and therefore have higher or lower levels of real risk from SLR, respectively.

Sourced Questions

Likert Scale

Questions 9 through 12 are sourced from the Six Americas Super Short Survey (Chryst et al., 2022) and are used to classify participants into groups based on their pre-map viewing perceptions of climate change. The Super Short Survey (SASSY) uses these four questions to classify participants into one of six groups based on their responses to those questions. These six groups include Alarmed, Concerned, Cautious, Disengaged, Doubtful, and Dismissive. Asking these questions at the start of the survey and then later dividing the participants into groups based on their responses helps identify how these two map viewing environments affect groups with differing perceptions and beliefs about climate change, which could be useful in identifying targeted climate change communication strategies. Minor alterations were made to the wording of the four questions, namely, the term ‘global warming’ was replaced with ‘climate change’, as this term captures a wider range of consequences than increases in temperature alone. Chryst et al. (2022) provide a resource for responses to be uploaded and classified based on their criteria, which was utilized for this study.

Questions 14 and 24 are sourced from Retchless's (2018) study. The aim of these questions is to gauge participants' perceptions of the risk that SLR poses to them during the current century. These are an integral part of this thesis, as one of the research questions this thesis seeks to answer is whether or not these two map viewing environments differ in how they affect perceptions of risk of SLR. A change in response to this question after viewing the map viewing environment would indicate that the environment had an impact on these perceptions.

Conclusion

This chapter examined several gaps in the current literature on the use of maps in climate change communication, including the lack of data on the effectiveness of static and interactive map viewing environments at influencing perceptions of risk and temporal distance of SLR, as well as any differences between the two environments in this regard. It then introduced four research questions that were formed to attempt to fill these gaps. This was followed by a review of methods used in similar studies to test the effectiveness of maps in climate change communication, and then an introduction of the methods and instruments that were created for this study, specifically, a survey and two map viewing environments. The following chapter presents the results obtained by administering that survey to a group of participants online.

Chapter 4
Results

The purpose of this study is to understand how different map viewing environments, namely static and interactive, affect individuals' perceptions of both the temporal distance and risk of SLR, as well as how these two environments affect individuals' willingness to support policies and implement individual actions with the goal of climate change and SLR adaptation and mitigation. The threat of climate change in general, and SLR in particular, on coastal populations requires that action be taken to protect people and property from the worst of its consequences (e.g. storm surges, destruction of coastal property, etc.). To enact policy changes beyond an individual's local community, for example, they must be willing to support and implement those changes, which first requires that they are aware of the risks and consequences associated with climate change. To spread awareness and gain support for climate change adaptation and mitigation policies and strategies, understanding which map viewing environments are able to communicate these consequences to help individuals understand the risks and temporal distance of SLR and climate change is an important element in this study.

In this study, 404 participants recruited through Amazon's Mechanical Turk were asked a series of questions in an online survey administered through Qualtrics XM to gauge their perceptions of the risk and temporal distance of projected SLR in Boston, Massachusetts. After responding to these questions, half of the participants were then shown a series of static maps depicting projected SLR in Boston at three time periods in the future (2030, 2050, 2070), while the other half were shown an interactive map viewing environment depicting those same temporal projections, but with the added ability to zoom, pan, and toggle on and off the various layers on the map. After viewing the environments, participants were again asked about their perceptions of risk and temporal distance of SLR. The assumption being that any changes in those perceptions reported by participants is due to exposure to the maps. However, it is acknowledged that there are additional external factors influencing participants' responses which this study may not fully account for.

The following chapter is organized into six sections. First, it presents the demographic characteristics of the study's participants. This is followed by an exploration of how their perceptions of SLR risk were influenced by the different map viewing environments. The third section discusses the impact of these environments on participants' perceptions of the temporal distance of SLR. Subsequently, the fourth section delves into the effects of the map viewing environments on participants' support for policies aimed at mitigating and adapting to SLR and climate change. The fifth section assesses participants’ willingness to take individual actions towards SLR mitigation and adaptation. Finally, the chapter concludes by analyzing participants' open responses, shedding light on their perspectives regarding climate change and SLR, and the influence of the maps on these views.

Participants and Demographics

The survey discussed in Chapter 3 (see Appendix A for complete survey) was made available to participants on Mechanical Turk on August 25, 2023, and remained open until September 12, 2023. Overall, 404 participants took part in the survey, and 361 answered all questions on the survey, resulting in a completion rate of 89.36% (non-completion rate of 10.64%). The average completion time was 13 minutes and 34 seconds, with a minimum completion time of 4 minutes and 17 seconds and a maximum of 19 minutes and 3 seconds. Incomplete surveys were not used in the analysis detailed in this section.

Participants were asked a series of demographic questions, such as their age, gender, education level, political affiliation, relative distance from both Boston and the ocean, and emotional connection to Boston (questions 1-7 on the survey). Of the 361 participants who completed the survey, 220 (60.9%) identified as male and 141 female (39.1%). A majority of participants identified as Democrat (205, or 56.8%), followed by 104 (28.8%) Republicans, and the remainder either Independent (49, or 13.6%) or Other (3, or 0.8%). Only 44 (12.2%) reported living within 10 miles from Boston, compared with 176 (48.8%) living between 10 and 100 miles from Boston and 141 (39.0%) living more than 100 miles from

Boston. Complete demographic data of the participants in this study can be found in Appendix B of this thesis.

Six Americas

The Six Americas is a classification system developed by the Yale Program on Climate Change Communication (YPCCC), which segments the American public into six distinct groups - Alarmed, Concerned, Cautious, Disengaged, Doubtful, and Dismissive - based on their beliefs, attitudes, and behaviors regarding climate change. Segmenting participants in such a way is useful for this study as it may help determine if the different map viewing environments affect participants differently based on their preexisting beliefs about climate change. Using participants' responses to questions 9-12 on their beliefs about climate change – derived from the Six Americas Super Short Survey (SASSY), a shortened version of the longer survey developed by YPCCC to segment individuals into these groups (Chryst et al., 2022) – participants were grouped into these six segments. To classify each participant into one of the Six Americas groups, their responses to questions 9-12 were uploaded to a tool on the YPCCC's website (https://climatecommunication.yale.edu/visualizations-data/sassy/). Figure **4-1** shows the percentages of participants from this study classed into each Six Americas based on their responses to questions 9-12 on the survey and Figure **4-2** shows how these percentages (dark blue bars) compared to the most recent national estimates (grey bars) of Americans' views on climate change, based off responses to the same questions asked in this survey, taken in December 2022.

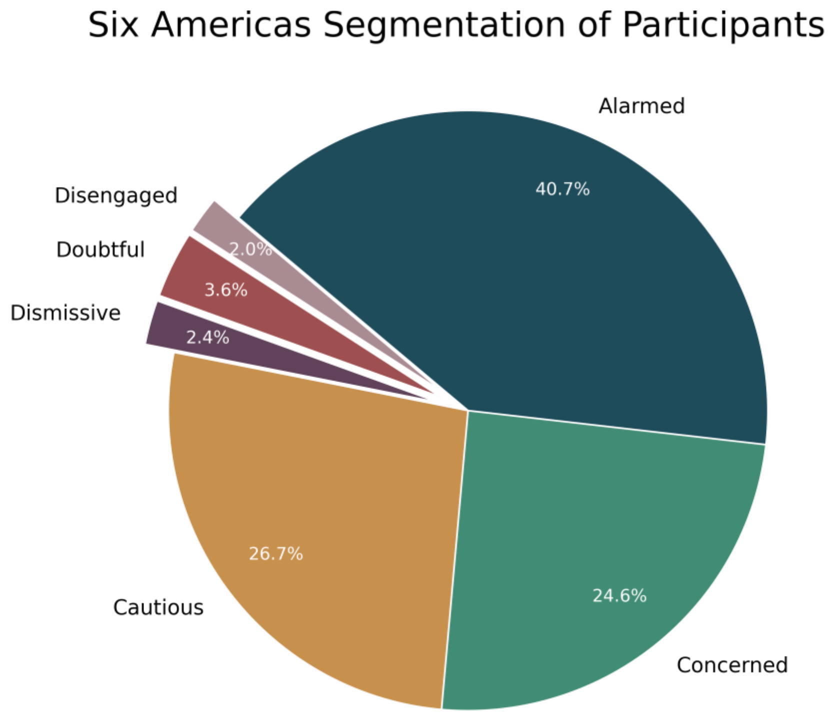

Figure **4-1**: Percentages of participants in this study in each SASSY Segment, based off of responses to questions 9-12 on the survey.

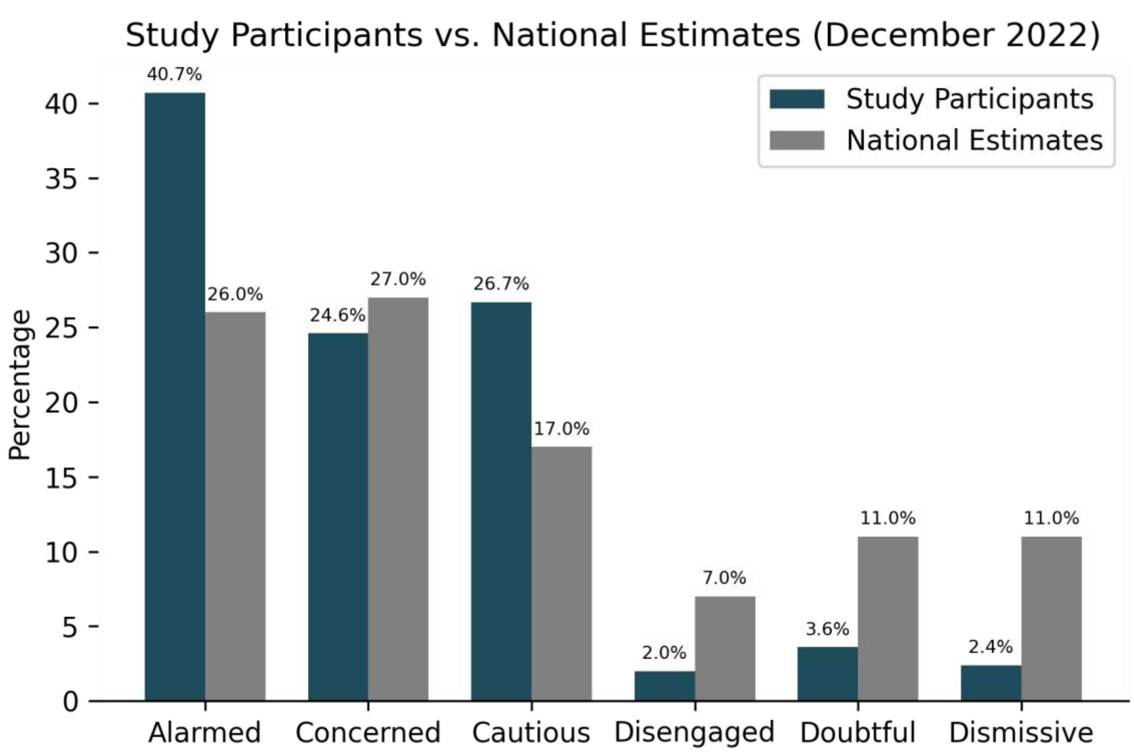

Figure **4-2**: This study's participants' SASSY Segment groupings compared to national estimates from December 2022.

In Figure **4-2**, both distributions appear to be positively skewed. Participants in this study appear to exhibit more of a skew toward the Alarmed, Concerned, and Cautious end of the scale when compared to national averages, with 92% of this study's participants landing on the left-side of the scale, compared with 70% of those in the national average. The greatest difference was found in the Alarmed segment (41% study participants compared to 26% national average). This difference could be attributed to a potential inherent bias among workers on Mechanical Turk, though Amazon does publicly disclose Turk demographic data. Alternatively, volunteer bias may have played a role in this trend. It is possible that this bias contributed, at least in part, to this skew, as the reported figures solely represent participants who successfully completed the survey. One can speculate that individuals who might have otherwise fallen into the Disengaged, Doubtful, or Dismissive groups may have opted out of or did not complete the survey upon realizing its focus on climate change. However, due to the incomplete responses from these individuals, it was not possible to accurately determine into which Six Americas group they might have been segmented.

Change in Perceptions of Risk of SLR

Understanding how participants' perceptions of risk posed by SLR were affected by the two viewing environments may be helpful for choosing which environments to use when attempting to convey such risks to the general public. This section looks at how these perceptions changed as a result of viewing the maps. This change was calculated by subtracting participants' pre-map-viewing risk perceptions of SLR (question 14, Appendix A; 0 = 'No risk at all' to 4 = 'Extreme risk') from their post-map-viewing risk perceptions of SLR (question 24, Appendix A).

Overall, most participants' risk perceptions of SLR remained stable while viewing the maps, across both viewing environments. This stability was evident as the median change in SLR risk perception among both groups was zero. However, for those who did report a change in risk perception of

SLR, in one way or the other, there was an observed difference between the two groups, specifically, 38.8% of those who viewed the interactive environment adjusted their risk perception compared with 29.0% of those who viewed the static environment. In the interactive environment, 21.9% respondents reported a decrease (orange bar) while 16.9% respondents reported an increase (cyan bar) in their perception of risk of SLR. In the static environment, 14.4% of respondents reported a decrease (orange bar) while 14.8% of respondents reported an increase (cyan bar). Figure **4-3** shows the frequency of participants whose perceptions of risk of SLR either decreased, remained unchanged, or increased post-map-viewing for both the interactive and static groups.

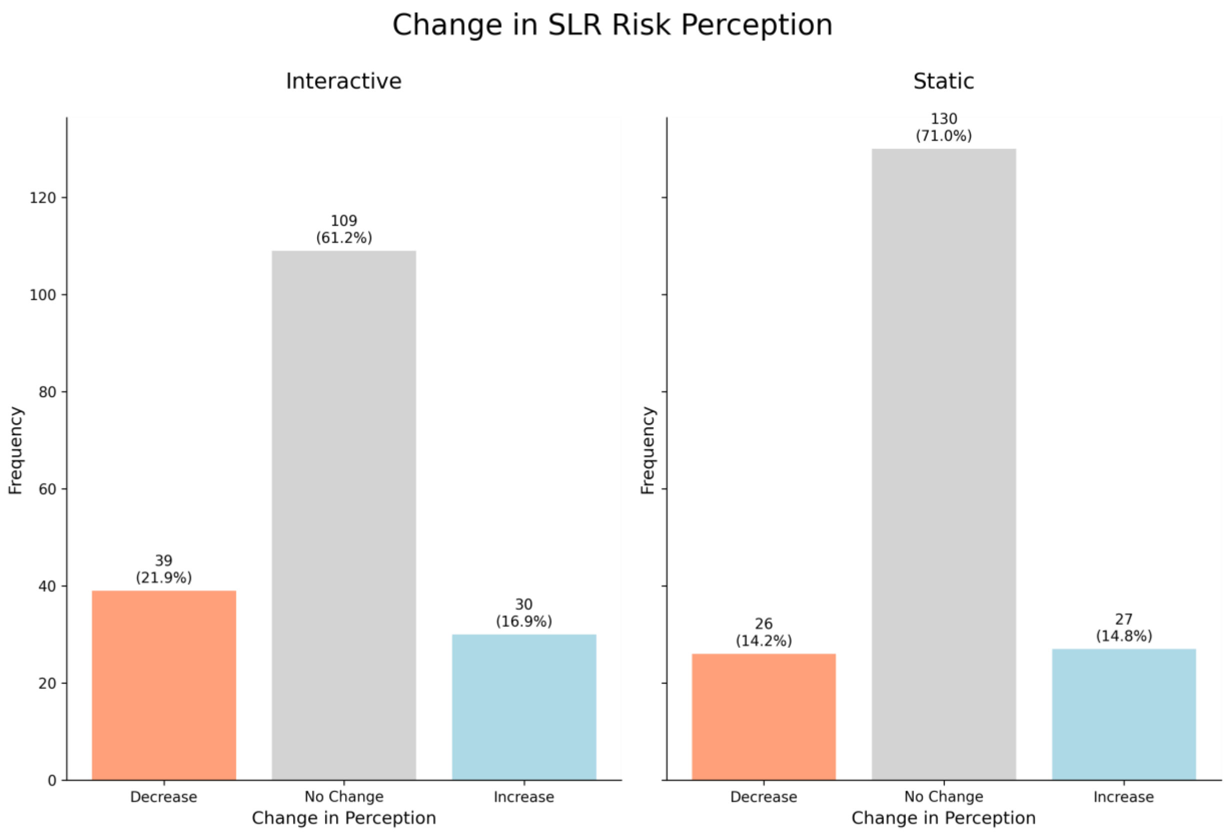

Figure **4-3**: Changes in SLR Risk Perception by map type, Interactive (left) and Static (right). Orange bars depict decreases in SLR risk perception, grey bars depict no change, and cyan bars depict increases in SLR risk perception.

Following the lead of Retchless' (2018) study on the effects of interactive map viewing environments on perceptions of risk of SLR with respect to an individual's geographic distance from the area being affected by SLR, a paired comparison test was employed on the results depicted in Figure **4-3**.

To evaluate, a Wilcoxon Signed-Rank Test was applied on data from the two groups separately. The Wilcoxon Signed-Rank Test is a non-parametric test used to determine whether there are differences between two groups. The test is used on paired samples to test the null hypothesis that the median of the differences between paired observations is zero. It is often used on ordinal data, which this data is. These analyses were performed using the Wilcoxon function from the SciPy package in Python.

The test produces two numbers: the test statistic (or *W*), which is the sum of the ranks of the differences between each participant's SLR risk perception, and the *p*-value, which determines the statistical significance of the result. In the case of the interactive group overall, *W* was 903.5 and the *p*-value was .0501. For all significance tests in this study, the commonly accepted *p*-value threshold of $<.05$ has been adopted. Thus, the *p*-value of .0501 does not imply a statistically significant change in risk perception of SLR among viewers. The static group overall yielded a *W* of 703.0 and a *p*-value of .9020. With these results, we cannot conclude that either environment had any statistically significant impact on participants' perceptions of SLR risk. Table **4-1** includes these results, along with results from the data when divided into various groups according to demographic data. Results of several demographic groups are discussed in the following section.

Table **4-1**: Wilcoxon Signed-Rank Test results of risk perceptions of SLR for all demographic groups

Demographic Group	*Interactive*	*Static*
Overall	*W* = 903.5 *p*-value = .0501	*W* = 703.0 *p*-value = .9020
Male	*W* = 217.5 *p*-value = .0880	W = 249.0 *p*-value = .5344
Female	*W* = 241.5 *p*-value = .2994	*W* = 80.0 *p*-value = .2994
Democrat	***W* = 180.0** ***p*-value = .0295**	*W* = 272.5 *p*-value = .8732
Republican	*W* = 156.0 *p*-value = .4000	*W* = 56.0 *p*-value = .7963
Independent	*W* = 16.0 *p*-value = .7630	*W* = 6.5 *p*-value = .7825
Alarmed	*W* = 158.5 *p*-value = .1069	*W* = 39.0 *p*-value = .6171
Concerned	*W* = 72.0 *p*-value = .1834	*W* = 68.0 *p*-value = .9702
Cautious	*W* = 57.0 *p*-value = .8536	*W* = 115.5 *p*-value = .8027
< 10 miles from Boston	*W* = 2.0 *p*-value = .2568	*W* = 9.0 *p*-value = .1573
10 - 100 miles from Boston	***W* = 256.5** ***p*-value = .0113**	*W* = 162.5 *p*-value = .7730
> 100 miles from Boston	*W* = 118.0 *p*-value = .5084	*W* = 82.0 *p*-value = .3537

Change in Perceptions of Risk of SLR by Demographic Group

According to the results presented in Table **4-1**, there were no statistically significant changes between the two map viewing environments on the two groups as a whole. However, when organized into various demographic groups, two of these groups did show statistically significant changes in risk perception of SLR: Democrats and participants located 10 to 100 miles from Boston. Furthermore, only participants within these two groups who viewed the interactive environment showed statistically significant changes in their risk perception of SLR.

Of those participants who identified as Democrats and viewed the interactive environment, 37.4% reported a change in risk perception of SLR after viewing the maps. According to Figure **4-4**, nearly twice as many participants (24.2%) reported a decrease in risk perception than those who reported an increase (13.2%). A Wilcoxon Signed-Rank Test on this group yielded a *W* of 180.0 and a *p*-value of .0295, indicating a significant result in the change. Figure **4-4** presents the results for this group.

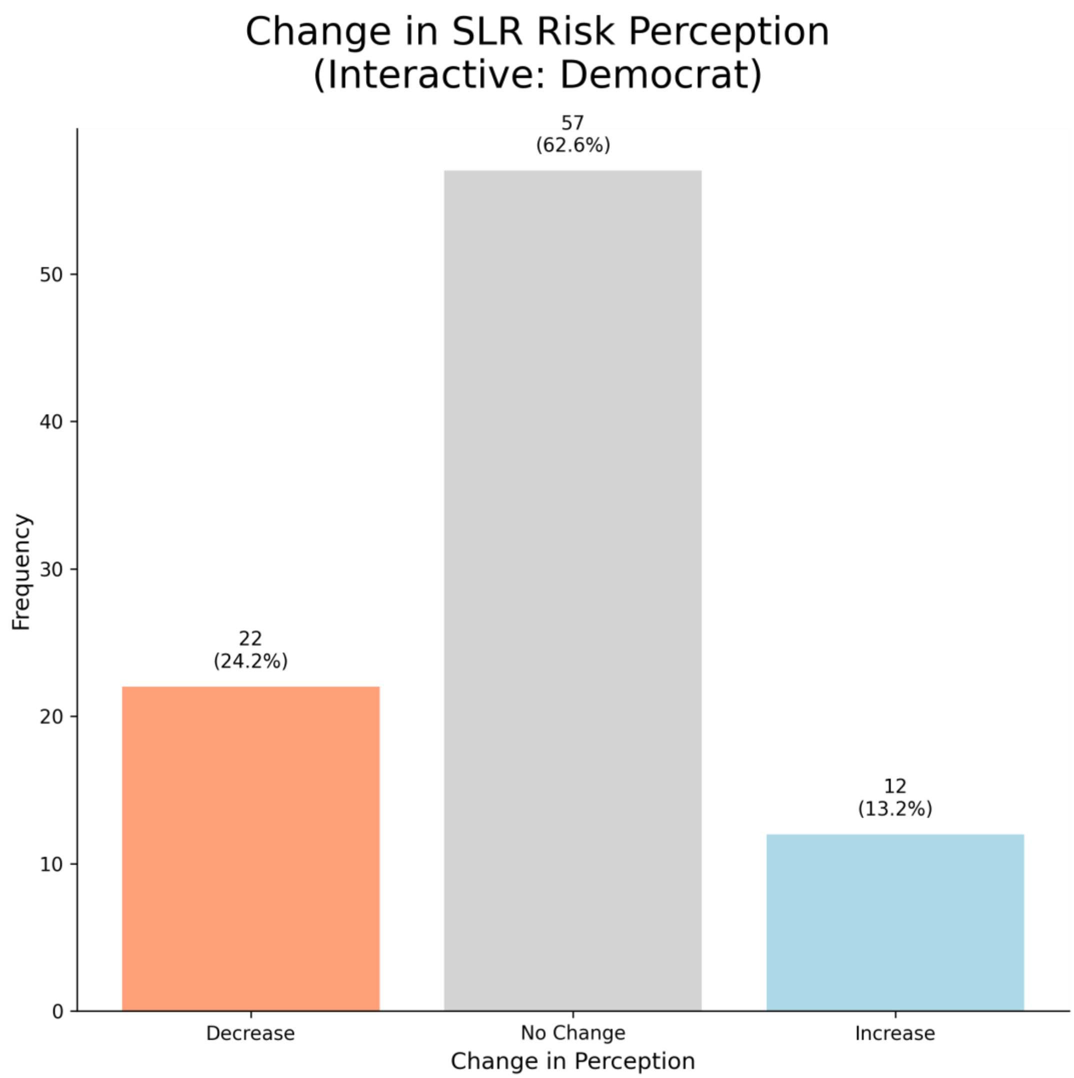

Figure **4-4**: Changes in SLR Risk Perception among participants who identified as Democrat and viewed the interactive environment.

Of the participants who viewed the interactive environments and reported to live between 10 and 100 miles from Boston – where the SLR was depicted on the maps – 44.7% reported a change in risk perception of SLR. Figure **4-5** illustrates that this group also had nearly twice as many participants report a decrease in risk perception (28.7%) compared to those who reported an increase (16.0%). This group yielded a *W* of 256.5 and a *p*-value of .0113, indicating that these changes in risk perception were statistically significant. Figure **4-5** reports the results for this group.

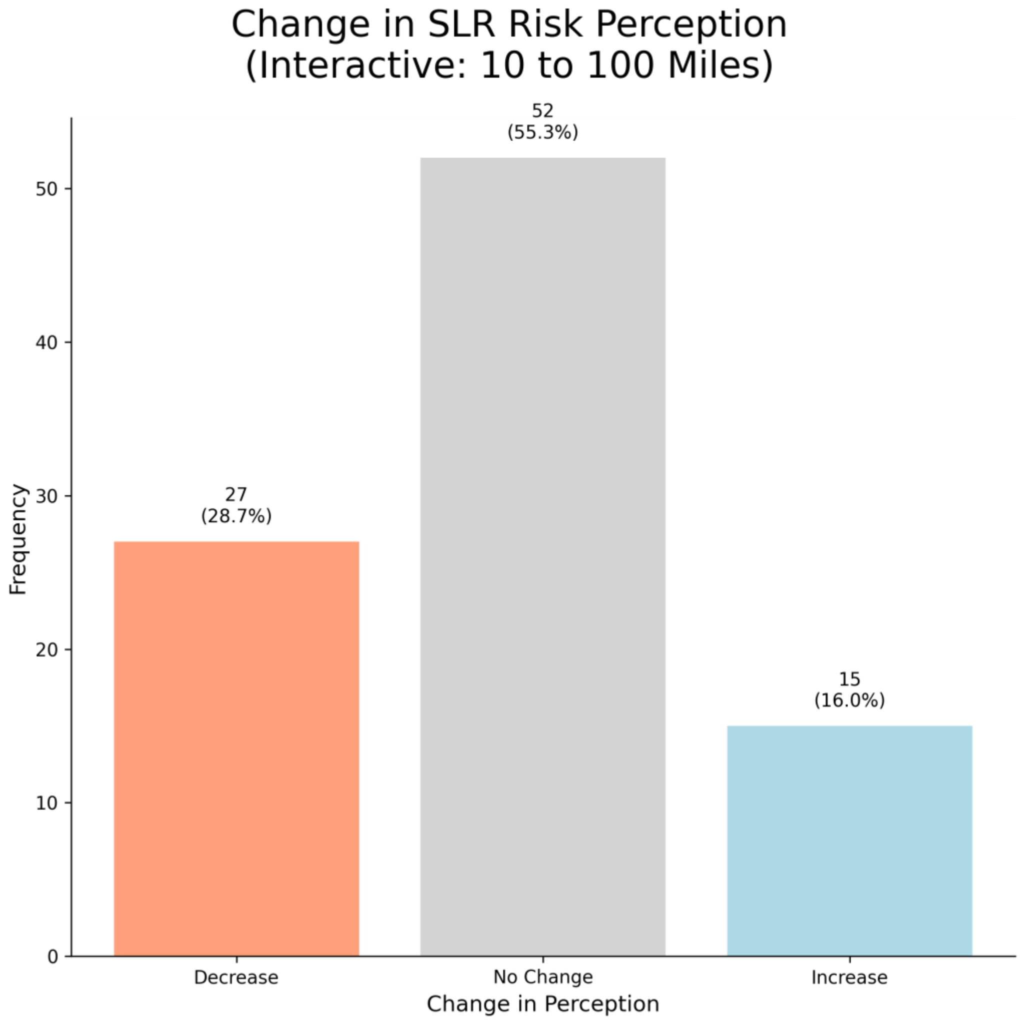

Figure **4-5**: Changes in SLR Risk Perception among participants living between 10 and 100 miles from Boston who viewed the interactive environment.

Change in Perceptions of Temporal Distance of SLR

Perceptions of temporal distance of SLR were measured in two ways: first, participants were asked how much time they perceived there to be before SLR would affect them personally (questions 15 and 25), and second, participants were shown a map of Boston with a green dot in a location that is projected to be inundated by 2070 (though participants were not provided with this temporal information when viewing the map) and asked to estimate the number of years they believed it would take SLR to inundate the area under the dot on the map (questions 22 and 28). These two questions were both asked pre- and post-map viewing to gauge how participants' temporal perceptions of SLR changed as a result of each viewing environment. The second question has an obvious limitation, which is that viewers are presented with SLR projections in the period between being asked these two questions, effectively giving them the answer. Though responses did not reflect that participants fully digested this information. The results suggested that either participants did not properly understand the information presented on the maps, something about the viewing environment altered their perceptions, or some other unknown factor was at play.

Change in Perceptions of Temporal Distance of SLR on the Personal Level

Figure **4-6** illustrates that before viewing the maps (pre-map condition), the average amount of time that participants believed they had before SLR would affect them personally was 5.26 years for the interactive groups and 9.16 years for the static groups. It is unclear why the responses of these groups differ. The post-map condition showed a similar pattern. The light blue bars in Figure **4-6** depict that, after viewing the maps, the interactive group's temporal perception increased to an average of 7.90 years, an increase of 2.64 years (50.19%). For the static group, the average rose to 10.72, an increase of 1.56 years (17.03%). Figure **4-6** reports these changes among both groups.

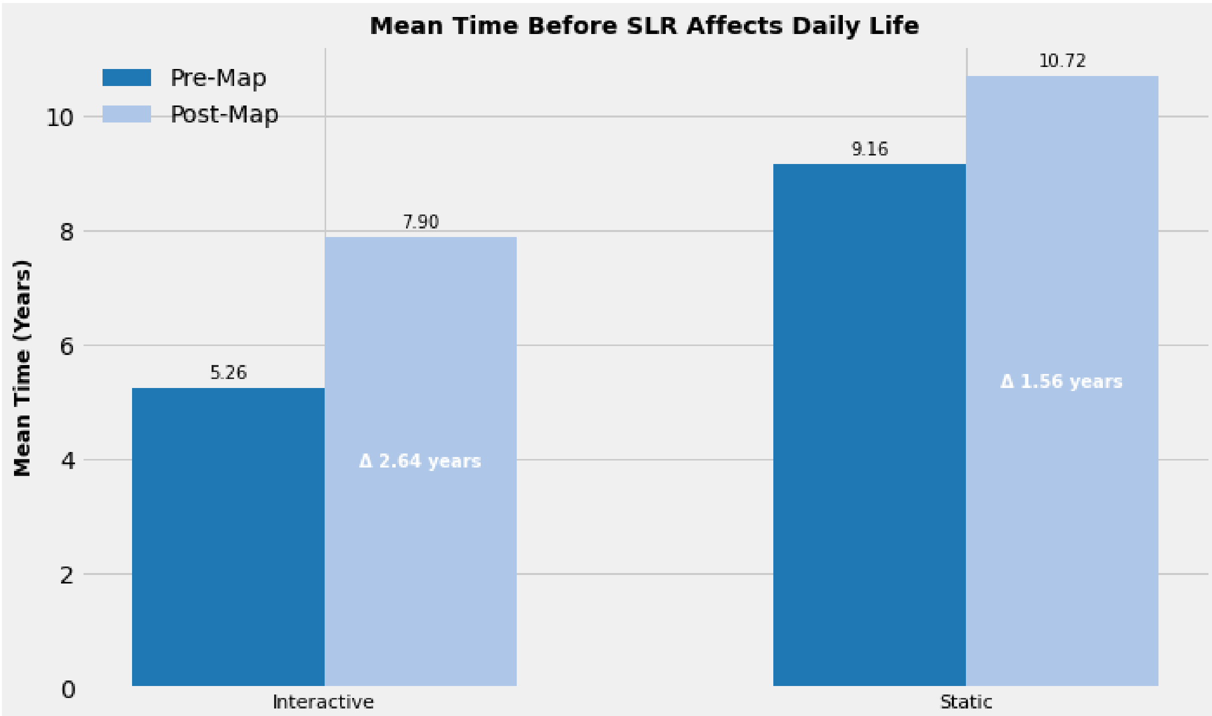

Figure **4-6**: Average number of years before participants believe SLR will affect their daily life pre- (dark blue) and post-map-viewing (light blue) for viewers of interactive (left) and static (right) environments.

Because these data are non-parametric and independent, a Mann-Whitney *U* test was used to test for any statistically significant differences between the effects of the two map viewing environments on perceptions of temporal distance. The Mann-Whitney *U* test ranks each data point within the two datasets based on their relative position within those datasets and then sums the ranks within each separate dataset. The output is a *U* statistic, which is calculated from the ranks of the data, and a *p*-value, which is used to help determine the significance of the results (i.e., whether a high probability that a difference exists between the two datasets and therefore between the two map viewing environments). These values were calculated using the mannwhitneyu function from the SciPy package in Python.

A Mann-Whitney *U* test was conducted to assess the statistical significance of the differences between the two environments and yielded a *U* of 16,112.5 and a *p*-value of .8415, indicating that there is no statistically significant difference was found. Table **4-2** shows that for all other demographic groups, no statistically significant differences existed.

Table **4-2**: Mann-Whitney U test results of perceptions of temporal distance of SLR at the personal level for all groups

Demographic Group	*Difference between Interactive and Static*
Overall	*U* = 16,112.5 *p*-value = .8415
Male	*U* = 5,820.5 *p*-value = .6168
Female	*U* = 2,516.5 p-value = .8471
Democrat	*U* = 5,495.0 *p*-value = .4148
Republican	*U* = 1,195.5 *p*-value = .4037
Independent	*U* = 283.0 *p*-value = .7094
Alarmed	*U* = 2,772.5 *p*-value = .7589
Concerned	*U* = 825.0 *p*-value = .4434
Cautious	*U* = 1,147.0 *p*-value = .6476
< 10 miles from Boston	*U* = 225.0 *p*-value = .7360
10 - 100 miles from Boston	*U* = 3,675.5 *p*-value = .5429
> 100 miles from Boston	*U* = 2,552.0 *p*-value = .7028

Change in Perceptions of Temporal Distance of SLR's Effect on Boston

When tested on their perceptions of time before SLR would affect a specific location in Boston, participants assigned to view the interactive environment responded with a pre-viewing average of 42.22 years (Figure **4-7**). For those assigned to view the static environment the average was slightly lower, at 38.82 years. Both of these pre-map averages are below the actual projected number of years before SLR would affect the location presented to them on the map, which is 2070, or 47 years from when this survey was administered, 2023. After viewing the maps, the interactive group's average was reduced to 30.75 years, a difference of 11.48 (-27.2%). The static group's average decreased to 31.68 years, a difference of 7.13 (-18.4%). However, a Mann-Whitney *U* test on these two groups yielded a *U* of 13,146.0 and a *p*-value of .5170, indicating that there is no statistically significant difference between the two groups, and therefore between the two map viewing environments. Figure **4-7** shows the average changes from pre- to post-map-viewing between these two groups while Table **4-3** summarizes the results from Mann-Whitney *U* tests on the two map viewing environments overall, as well as the various demographic groups.

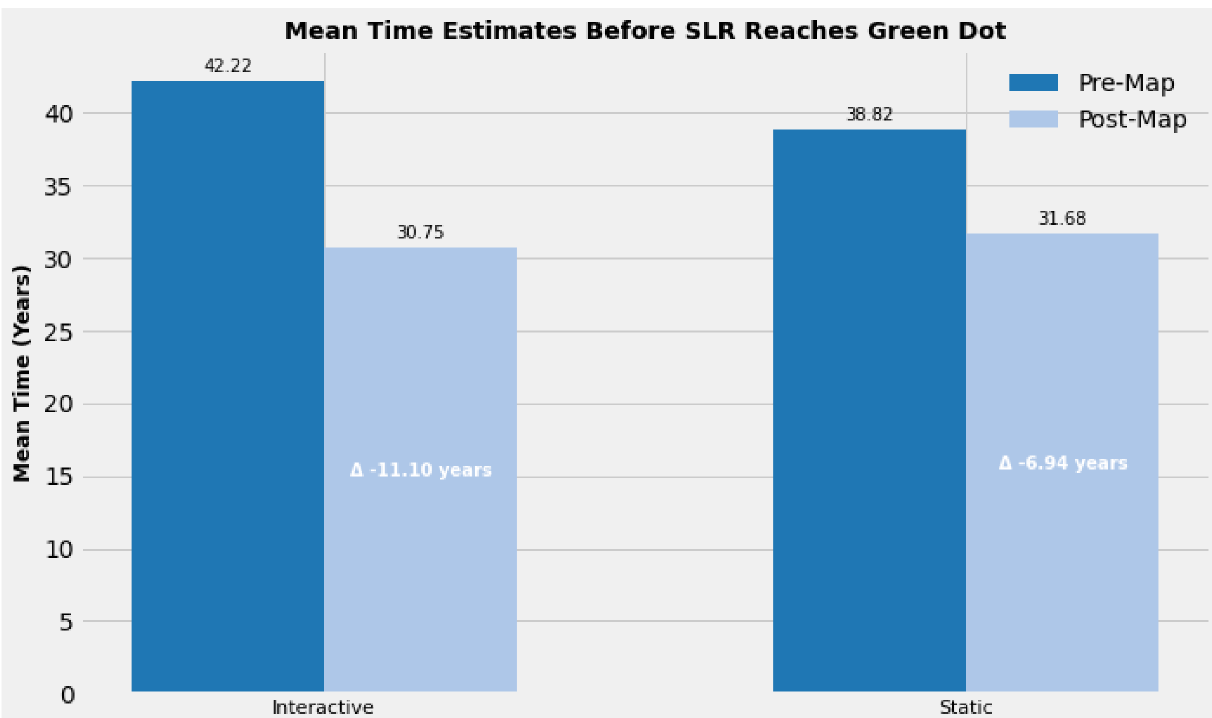

Figure **4-7**:Average number of years before participants believe SLR will reach an area of Boston highlighted by a green dot on a map pre- (dark blue) and post-map viewing (light blue) for viewers of interactive (left) and static (right) environments.

Table **4-3**: Mann-Whitney U Test results of perceptions of temporal distance of SLR's effects on Boston for all groups

Demographic Group	*Difference between Interactive and Static*
Overall	*U* = 13,146.0 *p*-value = .5170
Male	*U* = 4,712.0 *p*-value = .4872
Female	*U* = 2,110.0 p-value = .9079
Democrat	*U* = 4,917.5 *p*-value = .4684
Republican	*U* = 739.5 *p*-value = .1662
Independent	*U* = 221.0 *p*-value = .3534
Alarmed	*U* = 2,306.5 *p*-value = .4767
Concerned	*U* = 830.5 *p*-value = .4434
Cautious	*U* = 845.0 *p*-value = .9655
< 10 miles from Boston	*U* = 147.0 *p*-value = .6794
10 - 100 miles from Boston	***U* = 2,466.0** ******p*-value = .0221**
> 100 miles from Boston	*U* = 2,621.5 *p*-value = .2031

Change in Perceptions of Temporal Distance of SLR's Effect on Boston by Demographic Group

Although no statistically significant differences were present on temporal perceptions of SLR in Boston between the two map viewing environments, when individual demographic groups were observed, one group did exhibit a statistically significant difference between the two environments. Participants who reported living between 10 to 100 miles from Boston had their temporal perceptions affected in opposite directions, depending on which environment they viewed. For instance, the results portrayed by Figure **4-8** indicates that those who viewed the interactive environment initially responded with a projected 17.84 years before water would reach the green dot on the map but adjusted that projection down to 15.61 years after viewing the interactive maps for a change of -2.23 years (-12.5%). On the other hand, participants who viewed the static environment initially responded with a projection of 17.63 years but then increased that projection to 20.48 years after viewing the static maps for a change of +2.85 years (+16.17%). Figure **4-8** shows results from these two groups.

A Mann-Whitney *U* test performed on this group yielded a *U* of 2,466.0 and a *p*-value of .0221, indicating a statistically significant difference between these two map viewing environments in temporal perceptions of SLR in Boston.

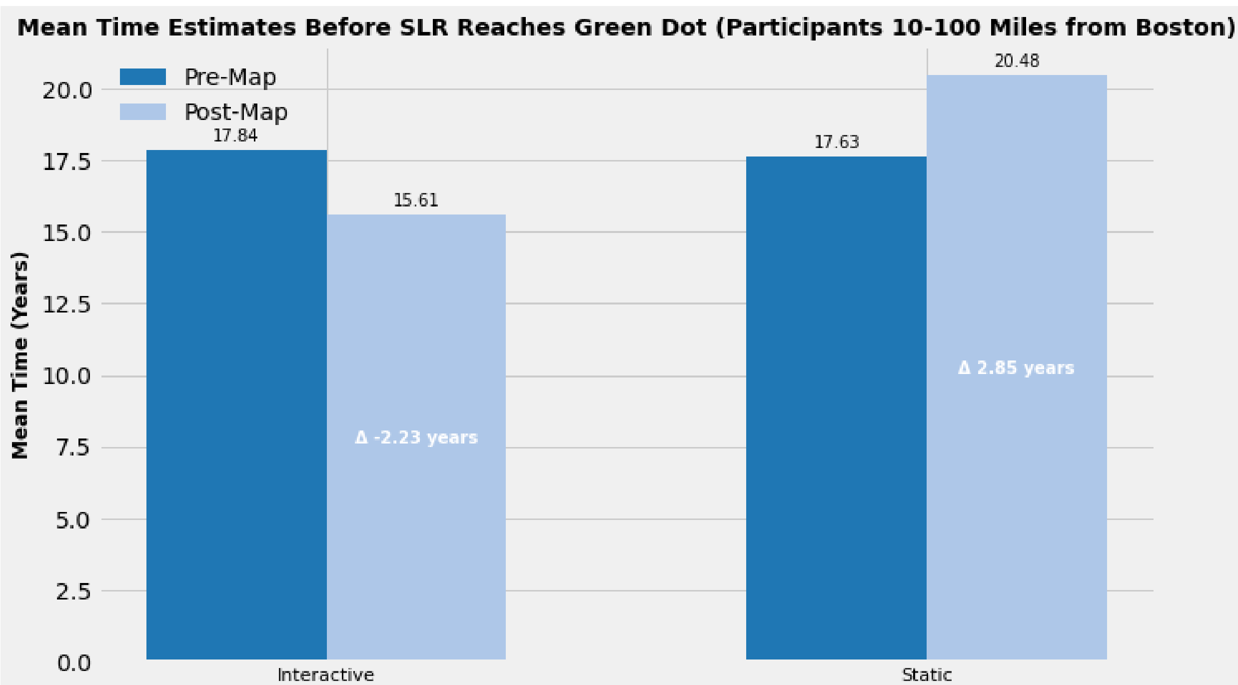

Figure **4-8**: Average number of years before participants believe SLR will reach an area of Boston highlighted by a green dot on a map pre- (dark blue) and post-map-viewing (light blue) for viewers of interactive (left) and static (right) environments who live within 10 to 100 miles from Boston.

Difference Between Estimates and Actual Projected Temporal Distance

The location where the green dot was placed on the map provided to participants is projected to be inundated due to SLR by the year 2070, according to projections used in this study provided by Boston's open data hub, Analyze Boston. Therefore, the true number of years before the area under the green dot would be inundated, at least according to these projections, is 47 years (this survey was administered in 2023). On average, participants in both groups reported estimates lower than that (i.e., temporally closer) both before and after viewing the map viewing environments, though there was a clear decrease by viewers of both environments after viewing them. Compared to the true projection (47 years), those who viewed the static environment estimated that the area under the dot would be inundated 15.31 years sooner. For the group that viewed the interactive environment it was 16.25 years sooner. A Mann-Whitney *U* test performed on these two groups yielded a *U* of 14,353.5 and a *p*-value of .9903, indicating that there is no statistical significance in the distance from the actual projected temporal distance between these two environments. However, it does appear that, overall, both environments impacted participants' temporal perceptions, making SLR seem nearer than the actual projections that they were shown in the map viewing environments. Table **4-4** presents the difference between participants' post-map estimated time before SLR will affect the area under the green dot and the projected time, in years, as well as the *U* and *p*-values yielded from Mann-Whitney *U* tests performed on results from the two environments for each demographic group. A negative value in column 2 or 3 indicates participants estimated SLR to inundate the area sooner than projections, whereas a positive value indicates an estimate of inundation further in the future than projections.

Table **4-4**: Difference between estimated temporal distance of inundation of area on the map under the green dot compared to actual projections

Demographic Group	Interactive	Static	*U*-statistic	*p*-value
Overall	-16.25	-15.31	14,353.5	.9903
Male	-17.03	-14.62	5,017.0	.6917
Female	-15.23	-16.53	2,360.0	.6691
Democrat	-22.22	-24.66	5,476.0	.1417
Republican	-19.66	-7.83	857.0	.4097
Independent	11.31	11.54	263.0	.9823
Alarmed	-18.28	-21.86	2,857.0	.2654
Concerned	-29.10	-5.21	618.5	***.0397**
Cautious	-30.33	-28.10	831.0	.6966
< 10 miles from Boston	-26.15	-37.08	204.0	.3026
10 - 100 miles from Boston	-31.39	-26.52	3,178.0	.5838
> 100 miles from Boston	7.19	2.07	2,577.0	.3711

When the differences among groups are observed, there is a wide range in difference between estimated and actual projected temporal distance. The largest of these differences can be seen from the group of participants living less than 10 miles from Boston who viewed the static environment, with an estimate of 37.08 years sooner than projections. The smallest comes from participants living more than 100 miles from Boston who viewed the static environment, which was over the projected value by just 2.07 years. The largest difference between the two environments occurred within the Concerned group, where participants who viewed the interactive environment estimated 29.1 years before projections compared to only 5.21 years before projections for those participants who viewed the static environment. A Mann-Whitney *U* test on this group yielded a *U* of 618.5 and a *p*-value of .0397, indicating a statistically significant difference between these two environments on perceptions of temporal distance of SLR in Boston.

Change in Support for Policies to Mitigate and Adapt to SLR

Participants were asked about their willingness to support policies and strategies designed to help cities mitigate and adapt to the effects of climate change and SLR. Examples of mitigation and adaptation strategies were provided, such as erecting levees and seawalls, and participants were also asked to provide examples of their own. Then, participants were given a range of options, from ‘very unlikely’ to ‘very likely’ and were asked to choose one that represents their estimated likelihood of supporting such policies and strategies both before (question 18, Appendix A) and after (question 26, Appendix A) viewing the map environments. These responses were then numerically coded so that changes in pre- and post-map-viewing responses could be analyzed in the same way that risk perceptions of SLR were analyzed, with percentages of participants whose responses decreased (i.e., reported a lower likelihood of supporting strategies), remained constant, or increased (i.e., reported a higher likelihood of supporting strategies).

In the group that viewed the interactive environment, 38.8% of participants reported a change, in one way or another, in willingness to support such policies and strategies after viewing the maps. Around a quarter (25.3%) reported an increase in willingness to support such policies and strategies compared to 13.5% reporting a decrease (Figure **4-9**). A Wilcoxon Signed-Rank Test on this group yielded a *W* of 821.5 and a *p*-value of .0143, indicating that this group exhibited a statistically significant change in willingness to support these policies and strategies (Table **4-5**).

Nearly half of the participants who viewed the static environment reported a change in willingness to support such policies and strategies (47.0%), with the number of participants reporting decreases equal to those reporting increases (23.5%). This group did not yield statistically significant results, however, with a *W* of 1808.0 and a *p*-value of .7718. Figure **4-9** shows the results from these two groups and Table **4-5** compares the yields from Wilcoxon Signed-Rank tests performed on these two groups, as well as the various demographic groups.

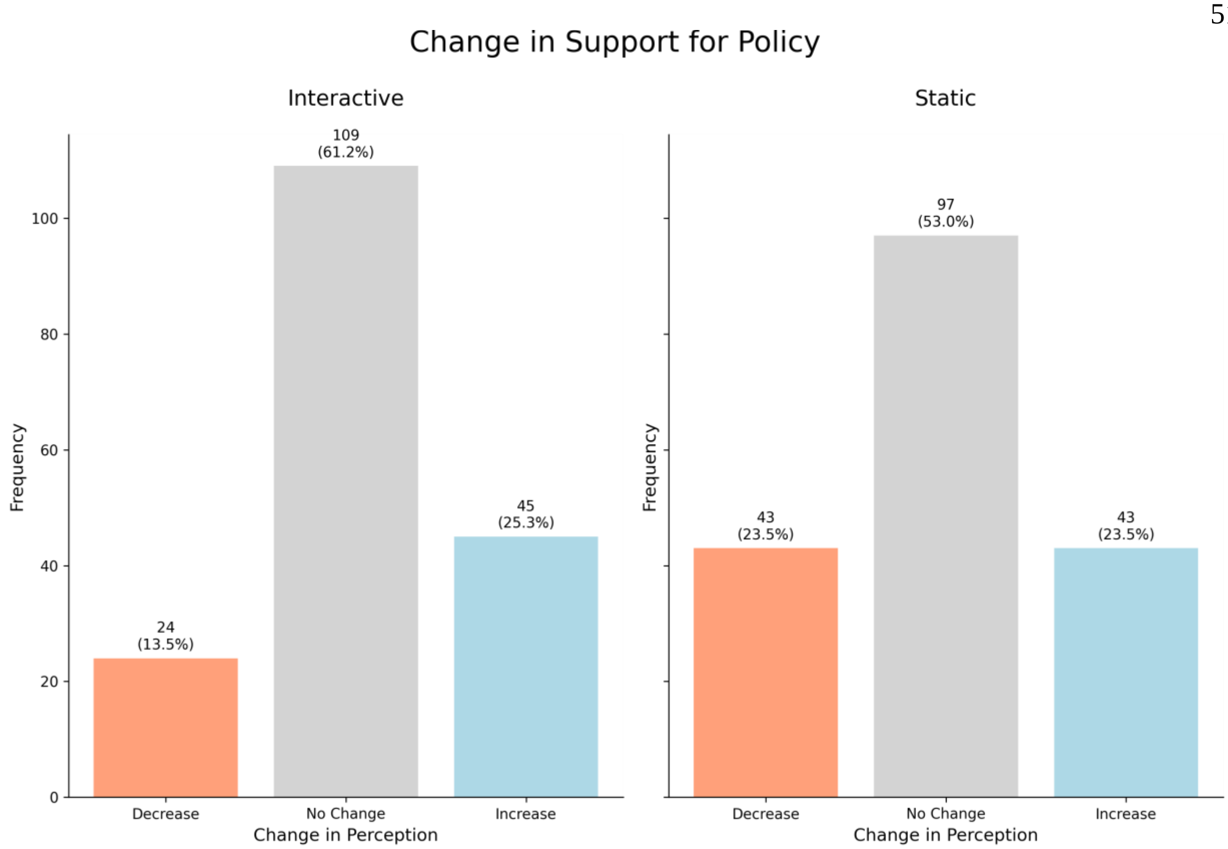

Figure **4-9**: Change in likelihood of supporting policies designed to mitigate and adapt to SLR among viewers of interactive (left) and static (right) environments.

Table **4-5**: Wilcoxon Signed-Rank Test results on change in SLR policy support for all demographic groups

Demographic Group	*Interactive*	*Static*
Overall	***W* = 821.5** ***p*-value = .0143**	*W* = 1808.0 *p*-value = .7718
Male	*W* = 344.5 *p*-value = .2301	*W* = 669.0 *p*-value = .8452
Female	***W* = 104.0** ***p*-value = .0190**	*W* = 258.0 *p*-value = .4643
Democrat	*W* = 272.5 *p*-value = .3059	*W* = 644.0 *p*-value = .6572
Republican	***W* = 103.0** ***p*-value = .0284**	*W* = 162.0 *p*-value = .9885
Independent	*W* = 2.0 *p*-value = .1308	*W* = 8.0 *p*-value = .0705
Alarmed	***W* = 116.0** ***p*-value = .0212**	*W* = 269.5 *p*-value = .8355
Concerned	*W* = 90.0 *p*-value = .5316	*W* = 92.0 *p*-value = .1167
Cautious	*W* = 28.0 *p*-value = .2038	*W* = 128.0 *p*-value = .4989
< 10 miles from Boston	*W* = 20.5 *p*-value = .8028	*W* = 42.0 *p*-value = .7815
10 - 100 miles from Boston	*W* = 299.0 *p*-value = .5580	*W* = 300.5 *p*-value = .1731
> 100 miles from Boston	***W* = 60.0** ****p*-value = .0084**	*W* = 201.0 *p*-value = .0844

Change in Support for Policies by Demographic Group

When organized into the various demographic groups, statistically significance was observed among several of the groups who viewed the interactive environment, though still not for those who viewed the static environment. This section examines the Female, Republican, Alarmed, and More than 100 miles from Boston demographic groups. Each of these groups yielded statistically significant results at the $p < .05$ level, and the group of participants living more than 100 miles from Boston yielded statistically significant results at the $p < .01$ level.

Of the participants who identified as female and viewed the interactive environment, 37.3% reported a change in support for policy after viewing the maps, with 26.7% reporting an increase in support compared to only 10.7% reporting a decrease in support. This group yielded a *W* of 104.0 and a *p*-value of .0190 (Table **4-5**).

Within the Republican group, 43.5% of participants who viewed the interactive environment reported a change in support for policy, with 30.6% reporting an increase and 12.9% reporting a decrease, yielding a *W* of 103.0 and a *p*-value of .0284 (Table **4-5**).

Of the participants grouped into the Alarmed SASSY Segment – the group “most worried about global warming and most supportive of aggressive action to reduce carbon pollution,” (Chryst et al., 2022) – who viewed the interactive environment, 36.7% reported a change in support for policy, with 26.6% reporting an increase and 10.1% reporting a decrease. This group yielded a *W* of 116.0 and a *p*-value of .0212 (Table **4-5**).

For those who viewed the interactive environment and reported living more than 100 miles from Boston, 36.0% reported a change in support for policy, with 30.8% reporting an increase and only 6.2% reporting a decrease. This group yielded a *W* of 60.0 and a *p*-value of .0084 (Table **4-5**).

Change in Support for Individual Action to Mitigate and Adapt to SLR

Participants were also asked about their willingness to implement individual actions to help cities mitigate and adapt to the effects of climate change and SLR. Example actions were provided, such as decreasing their own travel emissions by walking, biking, or taking public transportation instead of driving a personal vehicle, and participants were again asked to provide some examples of their own. Using the same options, from ‘very unlikely’ to ‘very likely, participants were then asked to respond with their likelihood of enacting such individual actions both before (question 19, Appendix A) and after (question 27, Appendix A) viewing the maps. These responses were then numerically coded so that changes in pre- and post-map-viewing responses could be analyzed to understand how support for such actions changed as a result of viewing the maps.

Of the participants who viewed the interactive environment, 43.3% reported a change in willingness to implement individual action after viewing the maps. Figure **4-10** suggests that more participants reported an increase (27.0%) compared to a decrease (16.3%) in willingness to implement individual action. A Wilcoxon Signed-Rank Test on this group yielded a *W* of 927.0 and a *p*-value of .8859, indicating that this group did not exhibit a statistically significant change in willingness to support these policies (Table **4-6**).

The group who viewed the static environment, on the other hand, saw more than half of participants report a change in willingness to support such policies (55.7%), with 33.3% reporting an increase and 22.4% reporting a decrease (Figure **4-10**). Though this group did not yield statistically significant results either, with a *W* of 1496.5 and a *p*-value of .6647 (Table **4-6**). Figure **4-10** shows the results from these two groups and Table **4-6** shows the yields from Wilcoxon Signed-Rank tests performed on these two groups, as well as the various demographic groups.

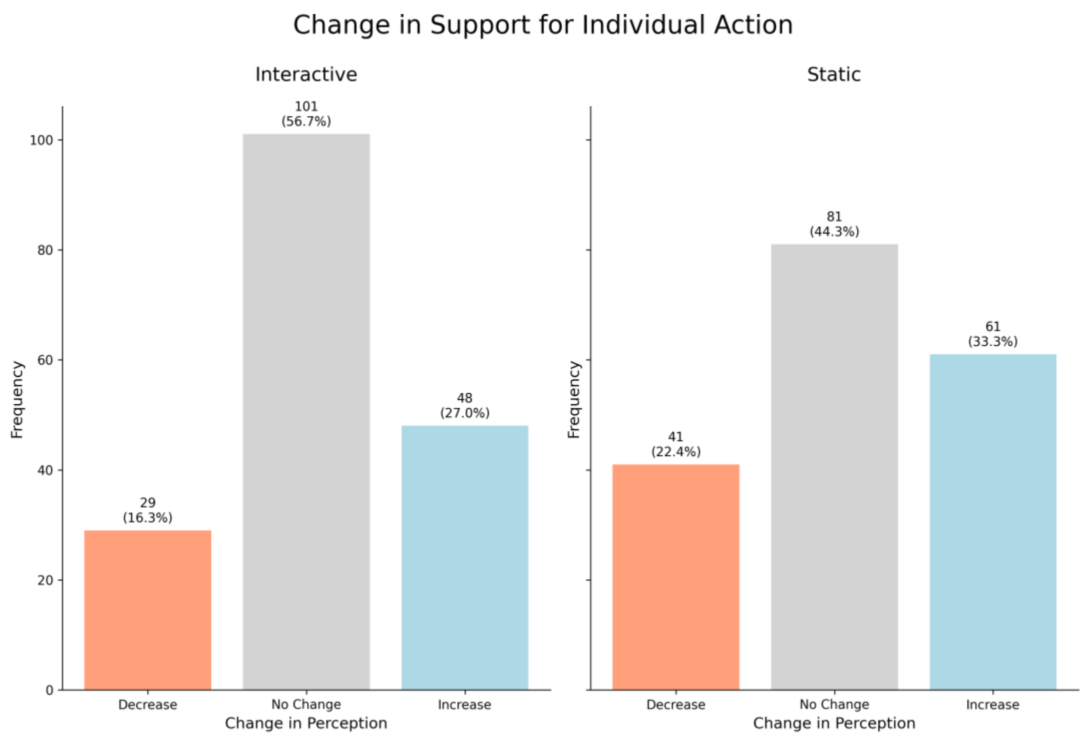

Figure **4-10**: Change in likelihood of taking individual action to mitigate and adapt to SLR among viewers of interactive (left) and static (right) environments.

Table **4-6**: Wilcoxon Signed-Rank Test results on change in support for individual action for all demographic groups

Demographic Group	*Interactive*	*Static*
Overall	*W* = 927.0 *p*-value = .8859	*W* = 1496.5 *p*-value = .6647
Male	*W* = 244.5 *p*-value = .3261	*W* = 550.5 *p*-value = .6847
Female	*W* = 156.5 *p*-value = .4030	*W* = 239.0 *p*-value = .8503
Democrat	*W* = 230.5 *p*-value = .7114	*W* = 650.0 *p*-value = .7049
Republican	*W* = 99.5 *p*-value = .1964	*W* = 80.5 *p*-value = .8197
Independent	*W* = 2.0 *p*-value = .1289	*W* = 8.0 *p*-value = .1312
Alarmed	*W* = 171.0 *p*-value = .4242	*W* = 199.0 *p*-value = .1965
Concerned	*W* = 31.0 *p*-value = .1467	*W* = 56.5 *p*-value = .8296
Cautious	*W* = 25.0 *p*-value = .7812	*W* = 143.5 *p*-value = .3893
< 10 miles from Boston	*W* = 10.5 *p*-value = .5271	***W* = 12.0** ***p*-value = .0348**
10 - 100 miles from Boston	*W* = 165.5 *p*-value = .2268	*W* = 204.5 *p*-value = .0899
> 100 miles from Boston	*W* = 136.0 *p*-value = .4420	*W* = 293.0 *p*-value = .9362

Change in Support for Individual Action by Demographic Group

While no statistically significant changes were present among either map environment as a whole, when organized into the various demographic groups, one group did exhibit a statistically significant change, specifically, participants who reported living less than 10 miles from Boston who viewed the static environment. Of this group, 56.0% of participants reported a change in support for individual action, with 52.0% of those reporting an increase and only 4.0% reporting a decrease. This group yielded a *W* of 12.0 and a *p*-value of .0348. Figure **4-11** shows the results from this group.

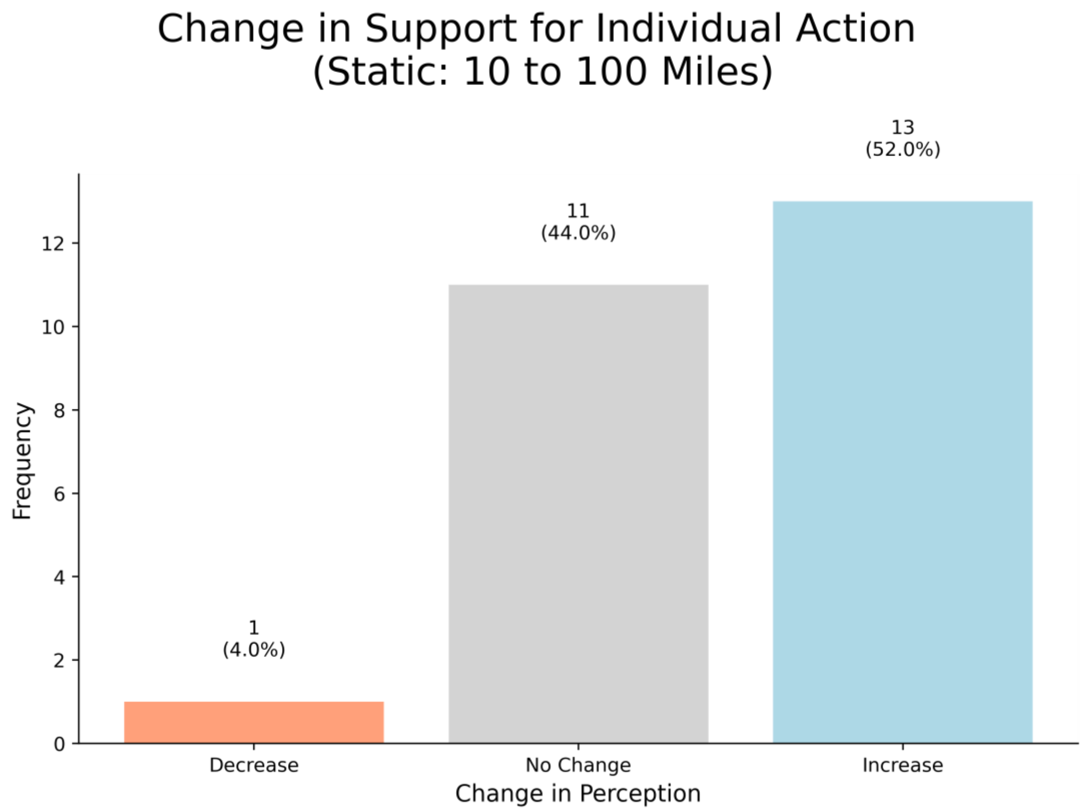

Figure **4-11**: Change in likelihood of taking individual action to mitigate and adapt to SLR among viewers of static environment who live within 10 to 100 miles of Boston.

Open Responses

Open response questions were used to gain a better understanding of how participants viewed climate change and SLR and to elicit a broader range of responses beyond what multiple choice questions alone could provide. Participants were asked about what comes to mind when they think of climate change (question 8); what risks they believe SLR poses to humanity (question 13); policies cities and governments can enact to mitigate and adapt to SLR (question 17); actions individuals can take to mitigate and adapt to SLR (question 20); which aspects of the map helped them understand SLR projections in Boston (question 23); and, for those who viewed the interactive maps, how they went about interacting with those maps (question 22.5).

Word clouds were used to analyze the words that participants used to respond to these questions. Word clouds provide a visual representation of textual information by presenting the most commonly used words from participants' responses grouped together in an image, with the most frequently occurring words depicted in the largest font on the image, and less frequently used words depicted in decreasing font sizes. Word clouds can be an effective method for analyzing qualitative data by allowing researchers and educators to evaluate which concepts are understood by participants and students and where understanding is lacking (DePaolo & Wilkinson, 2014).

For each of the open response questions on the survey, participants' responses were concatenated and then split into a Python dictionary containing each word and the frequency with which that word appeared in the responses. Words that were used in the phrasing of the questions were removed from these dictionaries to isolate unique ideas and knowledge from participants. Word clouds were then created from these dictionaries using the Word Cloud package in Python. Font color in these word clouds is used only to visually differentiate words and does not imply any qualitative or quantitative association between words. Word clouds created from responses about participants' understanding of climate change (question 8), their understanding of risks associated with SLR (question 13), and how they used the interactive environment (question 22.5) are discussed in this section. The remaining word clouds are not included, as they did not provide additional information pertaining to the primary objectives of this study.

Perceptions of Climate Change

Before providing participants with any information pertaining to SLR, they were asked about their general perceptions of climate change and what topics came to mind when thinking about climate change. Some of the words used most frequently include 'weather', 'temperature', and 'global', among others. (Figure **4-12**). While these words are consistent with ideas associated with the subject of climate change, we cannot conclude that participants necessarily understand how weather plays a role in climate change based off of the inclusion of these words alone.

The word cloud in Figure **4-12** also posits that SLR is perhaps generally understood to be a consequence of climate change by many of the participants, as another frequently used word in their responses were ‘sea’. Two similarly contextualized words associated with SLR, ‘level’ and ‘rising’ are also used with relative frequency (Figure **4-12**). This finding may help to conclude that, because participants already had some understanding of the effects of SLR, being introduced to new information about SLR alone was not the sole factor in any alterations in risk perception. The exposure to the two map viewing environments possibly played a role as well.

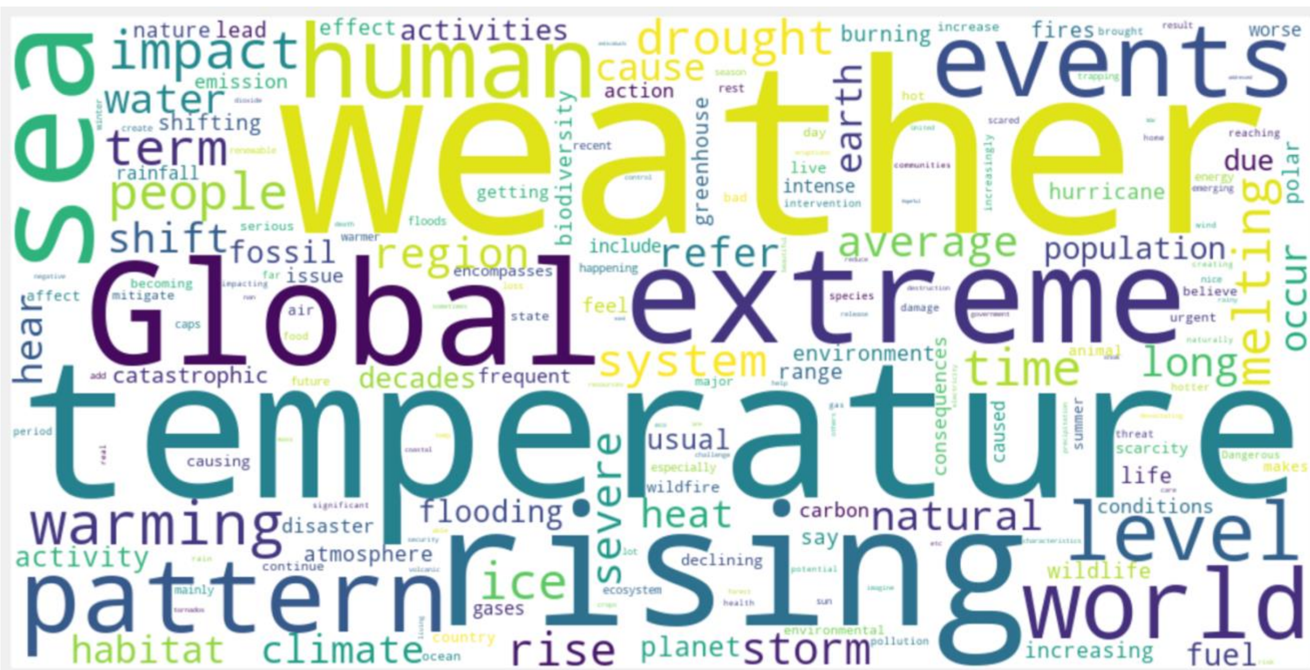

Figure **4-12**: Word Cloud created from responses to the question "What comes to mind when you think about climate change?"

Perceptions of SLR

After collecting information on participants’ perceptions of climate change in general, they were asked about their understanding of SLR specifically, and the risks associated with SLR. Participants seemed familiar with the fact that ‘low lying’ areas would be primarily affected by SLR (Figure **4-13**). They also used the words ‘permanent’ and ‘flooding’ frequently, and ‘inundation’ slightly less frequently, though it seems that many of the participants had some understanding that flooding of low-lying areas is a major risk associated with SLR. Fewer participants were aware of some of the other downstream consequences of flooding, such as erosion, damage to urban infrastructure, effects on agriculture and drinking water, etc. However, it is evident that at least some participants did have a more in-depth understanding of these consequences based off of the inclusion of words associated with such phenomenon, albeit with less frequency (e.g., ‘erosion’, ‘drinking water’, ‘agriculture soil’, etc.).

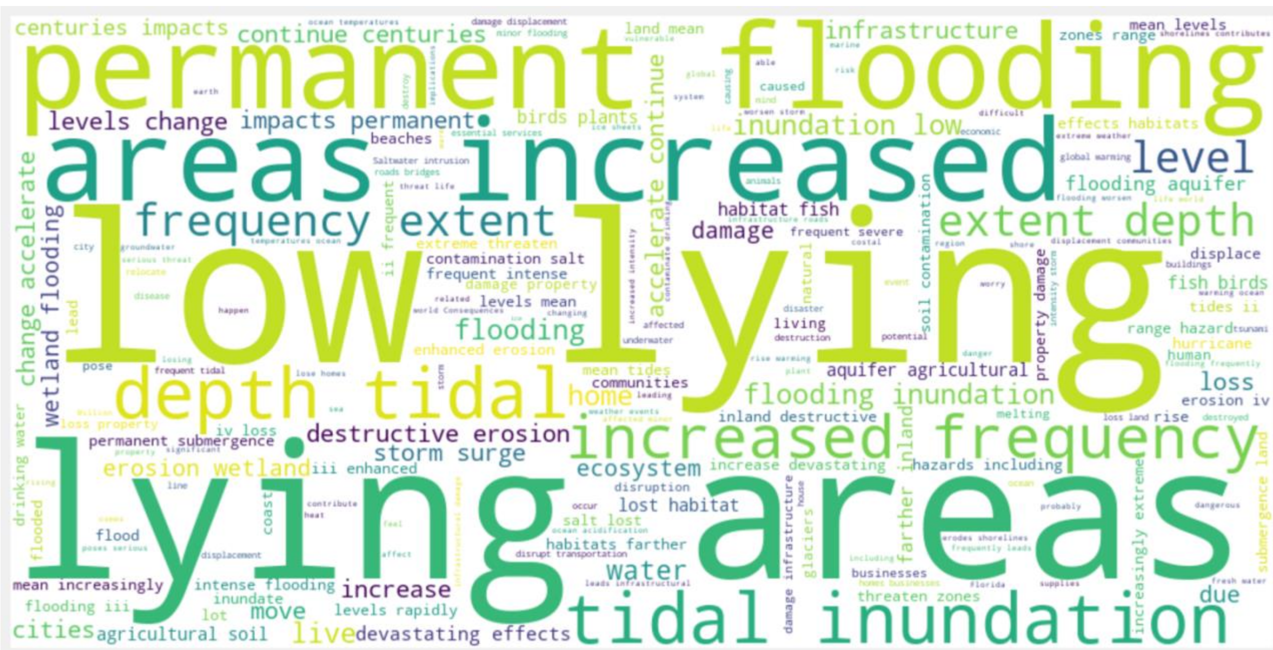

Figure **4-13**: Word Cloud created from responses to the prompt "Briefly describe what comes to mind when you think of the risks that sea level rise might pose to residents of coastal cities."

How the Interactive Map Environment was Utilized

Participants who viewed the interactive environment were given instruction on how to operate the environment but were not given any instructions or activities to perform beyond that. After interacting with the environment, they were asked to describe how they went about doing so. As Figure **4-14** illustrates, some of the most frequent responses include 'clicked’ (though where and how often they clicked is not known) and 'water' (presumably referring to the different layers depicting SLR). Some of the less frequently used terms include 'zoom', 'toggled', and 'search', which are some of the main advantages of the interactive environment over the static environment. However, just because participants did not include these words in their responses does not mean that they did not perform these actions while interacting with the maps.

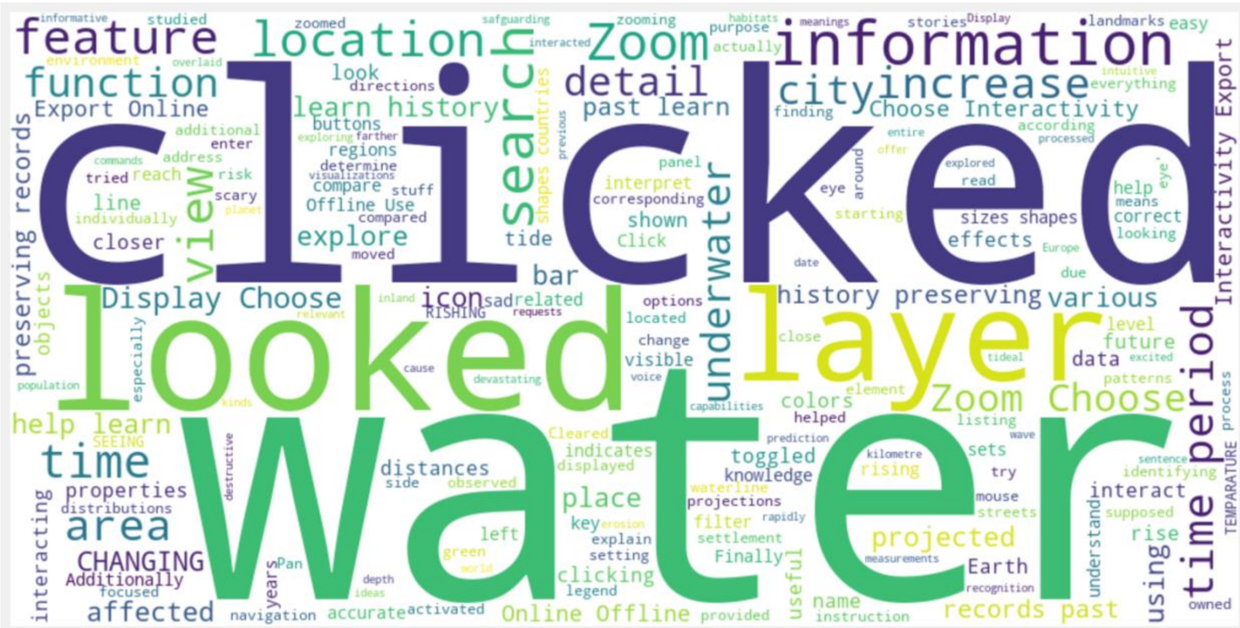

Figure **4-14**: Word cloud created from responses to the prompt "In a few words or sentences, explain how you went about interacting with the map."

Conclusion

This chapter has provided a detailed review of the participant characteristics and their responses to the survey. Beginning with an overview of the research purpose and methodology, it delved into the demographic and pre-existing perceptions climate change of participants before they interacted with the survey maps. The chapter then examined the influence of these maps on participants' perceptions of SLR risk, contrasting it with their initial perceptions prior to viewing the maps. Additionally, it explored the impact of the two map viewing environments on temporal perceptions of climate change and SLR, both at personal and societal levels. The analysis further extended to how these environments shaped participants' willingness to support policy initiatives and engage in individual actions for climate change mitigation or adaptation. The chapter concluded with an investigation into participants' overall perceptions of climate change and SLR risks, utilizing word clouds to analyze answers to open response questions. The next section will leverage these findings to address the research questions outlined at the start of this thesis, highlight methodological limitations in this study, and suggest directions for future research to address these limitations.

Chapter 5
Discussion

This chapter focuses on the lessons learned and implications of the findings from the survey presented in Chapter 4, as well as the limitations posed by the methodological approaches used in this study, and changes that could be incorporated into future research to address some of these limitations. The following chapter is organized into five sections. First, the research questions that this study addressed, and their relevancy and importance will be discussed. Second, the methodological approach that was used to address the questions and their usefulness will be examined. Third, the results presented in Chapter 4 will be summarized focusing on how those results answered the research questions, and the broader implications of lessons learned that were provided by these results. Fourth, the limitations present in this study will be reviewed. Fifth, this chapter will conclude with a discussion of ideas and directions for future research that may be useful to help answer these questions.

The Problem and its Relevance

Climate change and SLR are pressing issues that require action on the part of both governments and citizens, which first requires that those governments and citizens understand the consequences of climate change and SLR, as well as the time frame on which these consequences might be expected. Maps are commonly used to present the consequences of climate change and are especially helpful in depicting how and when certain geographic areas might be affected by SLR. This thesis reviewed several studies that have described how maps can influence perceptions of SLR (Retchless, 2014; Retchless, 2014b; Retchless, 2018; Hutton & Allen, 2022; Stephens & Richards, 2020). These studies often incorporated interactive map viewing environments, rather than static map viewing environments. The reason commonly cited for using these interactive environments over static ones is that interactive environments are somehow better at depicting SLR information, generally due to their ability to present large amounts of information to viewers through pan and zoom and pop-up functionalities (Retchless, 2014b). However, no study has attempted to quantify the effectiveness at understanding and changing perceptions surrounding the risks and temporal distance of SLR and climate change or the influence on policy support and individual action toward climate change mitigation and adaptation of interactive environments compared to their static counterparts.

The difference in this effectiveness between these two environments is important, not only because in how they present information to viewers, but also in the ease with which the layperson can access and interpret the information being depicted by them, and the complexity, time, and cost required to create them. If interactive environments are only marginally more effective, or there is no difference at conveying the risks and temporal distance of SLR or influencing individuals to support policies and act toward mitigation and adaptation compared to static environments, then static maps can be employed by climate change communicators for conveying those risks and temporal distance and influencing support and action from the general public. Discovering whether difference exists between these two environments have on perceptions of risk and temporal distance of SLR, as well as on influencing support for policies and individual actions designed to mitigate and adapt to climate change, is the focus of the ongoing study of understanding climate change communication through cartography.

Approach to Address the Problem

The methodology used in this study involved a pretest-posttest design, as was used in other similar studies designed to test the effectiveness that maps have on perceptions of SLR and climate change (Retchless, 2018; Houston et al., 2017; Hutton & Allen, 2022). The basic format of this methodology is to ask participants questions to gage a baseline of their opinion on a certain topic of interest, introduce a stimulus that might affect that opinion, then ask those same questions to quantify any change introduced by that stimulus. In this study, participants were initially questioned about their perceptions concerning certain aspects of SLR and climate change. Next, the stimulus was introduced. In this case, the stimulus was either a static or interactive map viewing environment depicting projected SLR in Boston for three time periods: 2030, 2050, and 2070. Finally, participants were asked the same questions that they were asked prior to viewing the stimulus to determine whether their perceptions changed after viewing the maps.

This approach assumes that, because no other differences were present in the stimuli other than the interactive or static nature of the map viewing environment, any changes in responses to the questions are due to the type of the environment being used. Obviously, causal effects cannot be determined with any certainty and a number of outside factors could also influence the changes in responses from participants. However, for the purposes of this study, without the ability to accurately account for such factors, the type of environment is assumed to be a significant contributor to the changes in perceptions. Future studies might further address the causal links of these map viewing environments on perceptions of SLR and climate change.

Significance of Results

This study quantified the differences that two different map viewing environments – static and interactive – have on perceptions of risk and temporal distance of SLR, as well as on influencing participants' willingness to support policies and individual actions to mitigate and adapt to SLR and climate change. Four research questions were developed and introduced in Chapter 3 of this thesis outlining the initial goals of this study, which were assessed by asking participants a series of questions surrounding their beliefs and perceptions of the risks and temporal distance of climate change and SLR (for full survey see Appendix A) and exposing them to maps depicting SLR projections. The full results from these surveys were reported in Chapter 4 of this thesis. The four research questions are presented in

Table **5-1**. To answer these questions, this section will explore insights that the results of this study provided.

Table **5-1**: Research questions developed to guide this thesis

Research Question 1 (RQ1)	Do static and interactive maps differ in communicating the risks of SLR?
Research Question 2 (RQ2)	Do static and interactive maps differ in decreasing perceptions of temporal distance of SLR?
Research Question 3 (RQ3)	Do static and interactive maps differ in increasing support for policies and individual action to mitigate and adapt to SLR and climate change?
Research Question 4 (RQ4)	What aspects or qualities of static or interactive maps help make SLR depictions feel temporally closer and/or prompt engagement with climate change?

RQ1

On the whole, neither environment proved more effective than the other in changing participants' perceptions of the risks associated with SLR. However, two demographic groups who viewed the interactive environment – *Democrats* and *participants living 10-100 miles from Boston* – both showed statistically significant changes in their levels of risk perception of SLR. In both instances, nearly twice as many participants reported a decrease in risk perception of SLR compared to those who reported an increase in risk perception of SLR after viewing the interactive map viewing environment depicting projected SLR in Boston for the years 2030, 2050, and 2070 (24.2% participants reported a decrease vs. 13.2% reporting an increase for Democrats, 28.7% vs. 16.0% for participants 10-100 miles from Boston). So, in some cases, and depending on who is viewing the maps, static and interactive maps do differ in communicating the risks of SLR. Though these changes point in the opposite direction than what might have been expected, considering the reported effectiveness of interactive mapping environments for depicting SLR information, as previous studies had suggested (Retchless, 2018; Hutton & Allen, 2021). That is, the interactive map environments used in this study are less effective at communicating the risks of SLR. Though another explanation is that perhaps participants from these groups had an exaggerated perception of risk of SLR to begin with, and those perceptions were reduced to levels more commensurate with the true risks after being presented with new information. However, determining what an appropriate level of perceived risk associated with SLR is beyond the scope of this study.

RQ2

There were two ways that this question was assessed: first from the personal perspective and then from the societal perspective. On the personal level, viewers of both environments reported increased temporal perceptions after viewing the maps (i.e., they believed that SLR would affect their lives at a point further in the future than is projected). However, neither of these groups yielded statistically significant results, and therefore the results cannot definitively conclude that either environment had any actual impact on personal perceptions of temporal distance of SLR.

As for societal perceptions, on the whole, viewers of both environments reported a decrease in temporal perception of SLR in Boston (i.e., they expected SLR to affect Boston sooner in time rather than later, after viewing the maps). This decrease was more pronounced among the participants who viewed the interactive environment (-11.1 years) compared with those who viewed the static environment (-6.9 years). Though, once again, the differences between the two environments did not yield statistically significant results.

The only subgroup for which there was any statistically significant difference between the two environments was those participants living between 10 and 100 miles from Boston. For this group, the map environments affected viewers’ perceptions of temporal distance of SLR in different directions. For those who viewed the interactive environment, the decrease in perceptions of temporal distance remained, albeit less pronounced when compared to the interactive group as a whole (-2.2 years vs. -11.1 years for the interactive group). Viewers of the static environment, on the other hand, reported an increase in perceptions of temporal distance (+2.9 years).

So while, on the whole, the two map viewing environments did not differ in decreasing perceptions of temporal distance of SLR, in a very specific circumstance, they did. Specifically, the interactive environment slightly decreased perceptions of temporal distance, while the static environment slightly increased them for participants living 10 to 100 miles from Boston.

RQ3

The two environments did differ in altering levels of support for policies designed to mitigate the effects of SLR. The interactive environment yielded statistically significant change, with twice as many participants reporting an increase in the likelihood of supporting such policies compared with those reporting a decrease in likelihood. This was also the case among several demographic groups within the interactive group, namely participants who identified as Female, Republican, those who were grouped in the Alarmed SASSY Segment, and those who live more than 100 miles from Boston.

When asked about their willingness to implement individual action to mitigate the effects of SLR, while both groups had more participants reporting an increase in willingness than a decrease, neither group showed a statistically significant difference from pre- to post-map-viewing. The only group that did experience a statistically significant change was the group of individuals living less than 10 miles from Boston who viewed the static environment. Within this group, after viewing the maps, 52% of participants reported an increased likelihood of implementing individual action.

RQ4

The specific aspects or qualities of the map environments that elicited the differences in changes outlined in the previous three research questions were difficult to determine from the results collected in this study. While interactive maps are generally considered to be more effective at presenting information on SLR and climate change, this study was unable to discern what aspects of the environment allowed for such assumptions. Participants did not provide information that proved insightful in answering these questions. One possible explanation for this conclusion is that participants of this study are not well versed in cartography, and therefore did not have the vocabulary to describe the aspects of the environments that they found particularly useful or ineffective. Future research is required to determine what aspects of the map environments are the most important in differentiating them in their abilities to communicate SLR.

Limitations to Methodology of this Study

This section will examine some of the limitations observed in the methodology used in this study to answer the research questions discussed in the previous section. While this study was designed to accurately gage participants' perceptions of the risks and temporal distance of SLR and climate change and their willingness to participate in the mitigation and adaption to SLR and climate change, the instruments used (e.g., maps and survey environment) and questions asked may not have provided the opportunities to collect the full range of perspectives related to perceptions of SLR risk. Seven limitations were recognized and are discussed here, though more certainly exist.

First, attempting to test participants' levels of support and intentions to act on climate change could be biased as the responses are self-reported intentions. A participant saying that they are likely to alter their lifestyle or support policy does not mean that they will. If actions do not follow stated intentions, then it is not clear what either map accomplishes. In order to capture whether a participant did in fact alter their lifestyle, for example, a follow up survey would be required at some future date. Also, the forms of engagement and action being asked about in this survey involve shorter term actions taken by participants. Actions that have longer-term impacts might include larger life decisions, such as deciding whether or not to move inland from a coastal area. The questions asked in this survey cannot provide answers for such longer-term decision making that will accompany the longer-term nature of SLR and climate change.

Second, any changes reported as a result of viewing these maps will likely not be lasting. Showing participants a map once, for only a few minutes is likely not enough to change their long-term perceptions of SLR. Skurka et al. (2023) examined the effects of repeated exposure to threatening climate change messages and found that when participants were shown threatening news stories describing the consequences of climate change daily over a seven-day period, their levels of fear and intentions to learn more and share the stories rose steadily and then leveled off around the fifth day. In contrast, participants who were shown zero or one threatening climate change related news story over a three-day span showed a steady decline in levels of fear after the first day. Further studies are necessary to determine how perceptions of SLR risk and temporal distance change over a longer period of time after exposure to SLR maps.

Third, in an effort to keep all variables constant, other than the static and interactive components of the maps, the map design used in this study was relatively basic. Some of the features that have been employed in maps used in other studies, especially interactive ones, include popups and labels on landmark locations, symbology depicting levels of uncertainty or a range of SLR heights under different scenarios, and supporting layers showing further effects of SLR, such as the potential impacts from stronger storm surges. Omitting these features likely limits some of the advantages of interactive maps that Retchless (2014b) and Stephens et al. (2016) point out, such as their ability to make SLR tangible through popups of landmarks or to convey complex information such as levels of uncertainty. Future studies could examine the effects that increased levels of complexity of interactive mapping tools have on viewers' perceptions of climate change by including one, some, or all of the features mentioned above and comparing their differences.

Fourth, the risks of SLR vary from place to place, in part because sea level does not rise at a uniform rate globally (NOAA, n.d.). The information being depicted on the maps in this study show the potential effects of SLR for Boston alone, which could see up to three feet of inundation by 2070. Effects of maps showing SLR in different locations on perceptions of risk could vary depending on the extent of SLR in the area. This study did not capture how all maps depicting SLR might affect perceptions, only those maps depicting SLR in Boston, and therefore cannot determine how to best present SLR information in all instances.

Fifth, as was previously mentioned, exposure to the maps alone cannot be proven to have caused any changes reported in perception of SLR or intentions to help mitigate or adapt to its consequences. Perhaps being introduced to new information about SLR, regardless of the medium in which it is presented, was the main contributor to these changes. Future studies could more accurately isolate the different variables present to establish a stronger causal link between map environment and perceptions of risk and temporal distance of SLR.

Sixth, participants were not being monitored as they interacted with the maps and therefore it is unclear what aspects of the maps participants spent the most time looking at or how they used the interactive environment. RQ4 sought to address which aspects about the environment types helped to alter participants perceptions, though without being able to monitor participants while they viewed the map, this question could not be answered. To better understand how participants utilize the features on the maps and how they spend their time interacting with the maps, more sophisticated monitoring methods could be employed on participants during the study. This could include eye- or mouse-tracking technologies that keep track of what participants are doing when looking at the different environments. While these methods are certainly more costly than the approach taken in this study, they could provide worthwhile insights into cartographic design for climate change communication.

Seventh, as discussed in the Six Americas section of Chapter 4, participants of this survey skewed more to the Alarmed side of the Six Americas scale when compared with national averages conducted by the YPCCC. The reasons for this are unclear. It is possible that the average Mechanical Turker leans more toward the Alarmed side of the scale when compared to the average American, though Amazon does not disclose this information. Another possibility is that, upon realizing that this survey was focused on climate change, participants who would fall towards the Dismissive end of the scale became disinterested and dropped out of the survey. Regardless of the reason, the fact that the majority of participants in this survey already held a view of climate change consistent with the Alarmed side of the scale may partially explain why a larger share of participants were reporting a decrease in perceptions of SLR risk after viewing the maps compared to those reporting an increase in perceptions of SLR risk. Their perceptions of risk of SLR prior to viewing the maps may have been more exaggerated than what might be considered proportionate with the actual projections presented in the maps of this survey. Therefore, being presented with the projections on the maps may have lowered their risk perceptions of SLR to be more proportionate with those projections.

Future Research

The following section will attempt to address some of the limitations discussed in the previous section as consideration for conducting future research on this topic. Future research might not only look to address the differences in the way that perceptions of risk and temporal distance of SLR are affected by maps between the two environments, but also those same differences within each environment. Seven recommendations for future research on this topic are discussed here

One of the main limitations of the maps used in this study was their relative simplicity in design and data used. These maps included several combinations of two basemaps (greyscale and satellite) and three data layers (SLR projections for 2030, 2050, and 2070). An advantage of using maps to depict SLR, and especially interactive maps, is their ability to incorporate both complex and personally relevant information in a way that is accessible and digestible (i.e., does not overwhelm the viewer with information). Unfortunately, for the purposes of this study, extra information and features were omitted in order to limit the difference between the two viewing environments to a single factor, whether or not they were interactive or static. One way to test the effects of extra information and/or features would be to employ maps with varying degrees of complexity (e.g., one map only including SLR projections, another including SLR projections and several pop-ups featuring points of interest, and another including both of those features, as well as another data layer representing storm surge projections) and to test how perceptions of risks and temporal distance of SLR change from viewing them. The increased complexity could be applied to only static map viewing environments, only interactive map viewing environments, or both environments, such as in this study.

To add to this approach, different geographic locations could also be incorporated into the maps to test how the place presented on the maps changes perceptions of SLR. As mentioned in the limitations, SLR does not affect each location in the same way, and therefore certain map viewing environments used to portray SLR in one location may not be as effective at portraying it in others. Studying the effects that these map viewing environments have on perceptions of risk and temporal perception of SLR in different locations could be helpful in addressing climate change communication on a larger geographic scale.

Another approach could allow participants to design their own maps, perhaps by providing them with a drag-and-drop environment where they can choose the symbology, the data to be depicted, and other features to be shown on the map. Participants could be instructed to design the maps that they believe aligns with a certain level of risk and/or urgency. This could give insights into which map features viewers consider to best associate with a given risk and urgency.

Future research may even take a similar approach and yield different results based on who is recruited for to participate, how they are recruited, and when they are recruited. Using Mechanical Turk is a relatively cheap and fast method for obtaining survey responses but may not provide the most representative sample of the population. Moreover, even within Mechanical Turk, how the survey was advertised and some of the leading questions of the survey may have further biased the participant pool to only those with a personal interest in climate change. As mentioned in the Limitations section of this chapter, participants in this survey skewed more toward the Alarmed side of the Six Americas scale when compared to national averages. This almost certainly impacts the results of this thesis as it restricts the testing of these map viewing environment to a certain subset of the US population, rather than a more accurate representation of the whole population. Better methods might be used in future studies for recruitment and screening to see how the results are affected by different participant pools with broader, more representative samples of the population as a whole.

Finally, one of the most important aspects of this study involves how the questions are designed, how they are asked, and in what order they are asked. Chapter 3 of this thesis covered the reasoning for including each question and the relevant past research and surveys that informed and helped to create those questions. However, there is always room for improvement and changes to both how the questions are asked and what type of answers are collected could result in different outcomes. Particular attention could focus on how perceptions of risk of SLR are measured. For example, questions 14 and 24 use a discrete scale of 0 to 4. This scale does not allow for participants to report minor shifts in risk perception, and therefore a continuous scale might prove more useful in future research. Another issue is that of the subjective nature of these responses, which makes it difficult to standardize. For example, what does it mean when participants report a risk perception of, say, 2. Moreover, with this type of scale, the intervals between each number are subjective. For example, a shift from 2 to 3 by one participant may imply a much larger jump in their perception of risk of SLR compared to the same shift in response by another participant. Future work might investigate other response options to measure such minor changes in perceptions of risk and temporal distance of SLR.

Conclusion

This chapter discussed the lessons learned and implications of the findings presented in Chapter 4, as well as some of the limitations uncovered throughout this thesis and several directions for future research to further answer the research questions posed in this thesis. It also reiterated the importance of this research in the ongoing study of climate change communication to avoid the worst possible consequences of climate change. The following chapter summarizes all that was learned and presented throughout this thesis.

Chapter 6
Conclusion

The purpose of this thesis was to quantify the effects that static and interactive map viewing environments of SLR have on perceptions of risk and temporal distance of SLR, as well as how these two environments affect viewers' support for policies, strategies and individual action to mitigate and adapt to climate change. Understanding how these environments communicate and influence perceptions of risk and temporal distance of SLR is a vital component in the ongoing effort to effectively communicate climate change to the general public. In order to enact the changes required to mitigate and adapt to the consequences of climate change, support and participation are required not just from those making decisions, but from those who will be affected by those decision as well. Fostering an understanding among the general public of the risks associated with SLR, and climate change in general, may help to increase that support. Communicating the urgency and timeframes on which many of these consequences may begin to impact humanity might further drive that support to levels that could allow for meaningful change.

In a review of the current literature conducted in Chapter 2 of this thesis, theories behind how individuals perceive risk and temporal distance of climate change were presented, along with research which looked into how maps might be used to affect those perceptions. What this literature lacked was a clear understanding of how different map viewing environments, namely static and interactive, differ in how they affect those perceptions. Chapter 3 introduced four research questions developed to attempt to quantify those differences, as well as the methods and data required to answer those questions, including an online survey completed by 361 participants through the Mechanical Turk platform. Chapter 4 provided analysis of the results obtained through that survey and Chapter 5 discussed how those results provide insight to the four research questions, described in brief here. First, overall, neither environment proved more effective than the other at increasing perceptions of the risks of SLR among participants surveyed. Second, overall, neither environment proved more effective than the other at decreasing perceptions of temporal distance of SLR among participants surveyed. Third, the interactive environment proved to be more effective at increasing support for policies and strategies to mitigate and adapt to SLR, despite showing no difference in its effects on perceptions of risk or temporal distance of SLR. Fourth, the aspects or qualities of these maps that influenced any of the differences that did appear between these two environments could not be ascertained with the methods utilized in this thesis. Based off of these insights, Chapter 5 also discussed several limitations to these methods, as well as recommendations for future research to further answer these questions.

A major takeaway from this thesis is that these map viewing environments have different effects on viewers, perhaps unsurprisingly, depending on the viewers' demographic characteristics, biases, and pre-existing beliefs about climate change. What is perhaps surprising is the directions in which some of these perceptions surrounding risk and temporal distance of SLR changed after these characteristics, biases and beliefs were considered. The study of climate change communication will greatly benefit from further research into how these different map viewing environments can be utilized among viewers of different backgrounds to effectively communicate the risks and temporal distance of SLR and climate change. It is clear that there is no one-size-fits-all approach here, and care must be taken with how this information is presented cartographically. What is important is that this information is presented accurately and urgently, as the gap between the present and the projections of SLR presented in this thesis continues to close.

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Appendix A

Complete Survey

1. (Multiple choice) What is your age?
   - 18 – 20
   - 21 – 29
   - 30 – 39
   - 40 – 49
   - 50 – 59
   - 60 or older

2. (Multiple choice) What gender do you identify as?
   - Male
   - Female
   - Prefer to describe: ________
   - Prefer not to say

3. (Multiple choice) What is the highest level of education you have completed?
   - Some high school
   - High school
   - Bachelor’s degree
   - Master’s degree
   - Ph.D. or higher
   - Trade School
   - Prefer not to say

4. (Multiple choice) What political party do you identify with?
   - Democrat
   - Republican
   - Independent
   - Prefer to describe: _______
   - Prefer not to say

5. (Multiple choice) Approximately how far do you live from Boston?
   - Less than 10 miles
   - 10 to 100 miles
   - More than 100 miles

6. (Likert Scale) Describe your emotional connection to Boston.
   - A very high connection
   - A moderate connection
   - A minimal connection
   - No connection at all

7. (Multiple choice) Approximately how far do you live from the ocean?
- Less than 10 miles
- 10 to 100 miles
- More than 100 miles

8. (Open-ended, character limit: 500) In a few words or sentences, describe what comes to mind when you think of climate change.

9. (Likert Scale) How important is the issue of climate change to you personally?
- Extremely important
- Very important
- Somewhat important
- Not too important
- Not important at all

10. (Likert Scale) How worried are you about climate change?
- Very worried
- Somewhat worried
- Not very worried
- Not worried at all

11. (Likert Scale) How much do you think climate change will harm you personally?
- A great deal
- A moderate amount
- Only a little
- Not at all
- Don't know

12. (Likert Scale) How much do you think climate change will harm future generations of people?
- A great deal
- A moderate amount
- Only a little
- Not at all
- Don't know

13. (Open-ended, character limit: 500) Sea level rise is one particular consequence of climate change. In a few words or sentences, describe what comes to mind when you think of the risks that sea level rise might pose to residents of coastal cities.

14. (Likert scale) How much risk do you believe sea level rise poses to humanity during this century? (0 = no risk at all, 4 = extreme risk)

15. (Text box) Approximately how much time do you believe you have before sea level rise begins to affect your daily life? Enter an approximate number of years.

16. (Likert scale) Building new infrastructure, such as levees and seawalls, to protect coastal cities from the effects of sea level rise is one strategy cities can take to protects its residents. How likely are you to support policies and politicians in favor of this strategy?

- Very likely
- Likely
- Somewhat likely
- Somewhat unlikely
- Unlikely
- Very unlikely

17. (Open-ended, character limit: 500) List some other strategies that cities can take to protect their residents from the effects of sea level rise.

18. (Likert Scale) How likely are you to vote for policies and politicians in support of the strategies you listed in your previous response?

- Very likely
- Likely
- Somewhat likely
- Somewhat unlikely
- Unlikely
- Very unlikely

19. (Likert Scale) One way that individuals can limit the effects of sea level rise is to decrease their travel emissions by walking, biking, or taking public transportation instead of driving their personal vehicle. How likely are you to implement such changes in your daily life?

- Very likely
- Likely
- Somewhat likely
- Somewhat likely
- Unlikely
- Very unlikely

20. (Open-ended, character limit: 500) List some other changes that individuals can make to limit the effects of sea level rise.

21. (Likert Scale) How likely are you to implement the changes you listed in your previous response in your daily life?

- Very likely
- Likely
- Somewhat likely
- Somewhat likely
- Unlikely
- Very unlikely

Use this map to answer the following question.
[Map of Boston showing current sea level is displayed with a point over part of the city]
22. (Text box) How many years do you expect it to take before the water level reaches the green dot?

The following maps depict projected sea level rise in Boston for the years 2030, 2050, and 2070. Areas in blue represent those which will be under water under current climate change projections. Take a few minutes to view these maps and then answer the questions that follow. [Link to interactive map]

OR

The following link will direct you to an interactive map of sea level rise in Boston. Take a few minutes to read the instruction and explore the map. Check the box to confirm you have viewed the map, then answer the questions that follow.
[Show a series of six maps showing the projected SLR in Boston for 2030, 2050, 2070 with both a simple gray base map and a satellite imagery map.]

22.5. *Interactive Map Only* (Open-ended, character limit: 500) In a few words or sentences, explain how you went about interacting with the map.

23. (Open-ended, character limit: 500) In a few words or sentences, explain which aspects of the maps, if any, helped you to understand sea level rise projections in Boston?

24. (Likert scale) How much risk do you believe sea level rise poses to humanity during this century? (0 = no risk at all, 4 = extreme risk)

25. (Text box) Approximately how much time do you believe you have before sea level rise begins to affect your daily life? Enter an approximate number of years.

26. (Likert Scale) Thinking back to the examples you listed of strategies that cities could implement to protect their residents from the effects of sea level rise, how likely are you to vote for policies and politicians in support of such strategies?

- Very likely
- Likely
- Somewhat likely
- Somewhat unlikely
- Unlikely
- Very unlikely

27. (Likert Scale) Thinking back to the examples you listed on how an individual could contribute to limiting the effects of sea level rise, how likely are you to implement such changes in your daily life?

- Very likely
- Likely
- Somewhat likely
- Somewhat unlikely
- Unlikely
- Very unlikely

Use this map to answer the following question.
[Map of Boston showing current sea level is displayed with a point over part of the city]
28. (Text box) How many years do you expect it to take before the water level reaches the green dot?

Appendix B

Demographics of Participants

Demographic	Interactive	Static	Overall
Gender			
Male	103	117	220
Female	75	66	141
Age Range			
21-29	42	38	80
30-39	83	78	161
40-49	23	37	60
50-59	21	20	41
60 or older	9	10	19
Education Level			
Some high school	1	2	3
High School	22	22	44
Bachelor's degree	108	116	224
Master's degree	38	39	77
Ph.D. or higher	5	2	7
Trade school	4	2	6
Political Affiliation			
Democrat	91	114	205
Republican	62	42	104
Independent	23	26	49
Other	1	2	3
Distance from Boston			
Less than 10 miles	19	25	44
10 to 100 miles	94	82	176
More than 100 miles	65	76	141
Emotional connection to Boston			
A very high connection	35	35	70
A moderate connection	86	84	170
A minimal connection	30	33	63
No connection at all	27	31	58
Distance from the ocean			
Less than 10 miles	34	33	67
10 to 100 miles	92	98	190
More than 100 miles	52	33	85