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LETTER

The impact of frames highlighting coastal flooding in the USA on climate change beliefs

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Abstract There is a pressing need to find ways to communicate information about climate change effectively and in terms that resonate with diverse audiences. We conducted a survey-experiment to evaluate how textual and visual frames that highlight coastal flooding in two major US cities as a result of future sea level rise shape individuals' perceptions about the effects on coastal communities, concern for these places, and belief in climate change's existence. We build on extant literature by focusing on the impact of an understudied frame using animated maps that illustrate future flooding that will occur as global temperatures rise. We find that exposure to such messages increases perceptions that sea level rise will have negative impacts on coastal communities, concern for these communities, and belief in climate change.

Average temperatures are currently rising at a pace not seen before in the past 1300 years, and most of this climate change is likely human-induced (IPCC Fifth Assessment Report 2014). The US public, however, remains sharply divided along partisan and ideological lines over both the existence of climate change and its anthropogenic causes, and therefore the efficacy of policies that would address this issue (Bolsen et al. 2015; McCright and Dunlap 2011; Palm et al. 2017). The lack of public consensus obstructs the development and implementation of policies that would address climate change (Druckman 2015). If the USA is to respond promptly and effectively to this environmental risk within its democratic mode of decision-making, it will be important to identify effective communications that resonate with diverse audiences so that a consensus can be developed.

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1 Strategic framing and persuasive messaging on climate change

There is a growing interest among scholars across disciplines in understanding how messages that highlight different aspects of climate change—such as its economic, environmental, public health, national security, moral consequences, or other relevant considerations, such as the nature of the science and whether a consensus exists—affect beliefs about the existence and risks of climate change, concern about its impacts, and what citizens might be willing to do, or policies they would support, to mitigate its eventual effects (Kahan et al. 2012; Lewandowsky et al. 2013; Nisbet 2009; O'Neill et al. 2015). Much of this work tests how exposure to *frames in communication*—i.e., words, phrases, or images that highlight a specific consideration about an attitude object—influences opinions and beliefs associated with climate change (Chong and Druckman 2007; Druckman 2011).

Although a growing literature examines how exposure to different types of "emphasis frames" influences beliefs about climate change, only recently have scholars begun to examine the impact of climate change *imagery* on individuals' opinions and behaviors (Hart and Feldman 2016; Leiserowitz 2006; Myers et al. 2012; O'Neill 2013; Sheppard 2005). In a review of the literature on this nascent area of scholarly interest, O'Neill and Smith (2014) explain that images have unique qualities that "aid in information exchange: they can draw viewers in through vivid and emotional portrayals, they aid in remembering information, and… they can transcend linguistic and geographic barriers" (p.73). The selection of images can accentuate specific aspects of climate change, ultimately influencing related beliefs and behaviors and potentially facilitating engagement with this issue (Hart and Feldman 2016; O'Neill and Nicholson-Cole 2009; O'Neill et al. 2013). Images that highlight politics or spatially and socially distant locations, as for example with pictures of political figures, polar bears, or melting glaciers that dominate media coverage's visual landscape (Feldman et al. 2015; Lorenzoni et al. 2006), can lead to a "psychological distancing effect." In this case, climate change is seen as only affecting future generations and distant or exotic locations but not local places and communities (Lorenzoni et al. 2007; Pidgeon and Fischoff 2011).

One way to reduce the psychological distance of climate change and engage the public is by communicating its effects on familiar people and places (Scannell and Gifford 2013; Sheppard 2005). For instance, frames that highlight the local impacts of climate change and that provide information that is detailed, realistic, and relatable can foster climate change engagement and opinion change (Manzo 2010; Shaw et al. 2009; Sheppard et al. 2011). In addition, simple visual frames (e.g., pie charts) and textual depictions about climate change (e.g., that a scientific consensus exists) can shift beliefs toward the consensus scientific position (Van der Linden et al. 2014). One recent study found that exposure to a map highlighting the local impacts of coastal flooding in Florida on college students shifted the risk perception of respondents who were initially doubtful or cautious about climate change, suggesting that using interactive maps showing sea level rise may be an effective "frame" for engaging skeptical audiences (Retchless 2017). The author explains, "Although interactive sea level rise maps are one of the more popular means of depicting detailed and local sea level rise impacts, their potential for engaging audiences remains largely unevaluated" (p.6). In this paper, we describe how frames that highlight sea level rise, both in a text and using animated maps illustrating flooding in two major US cities, affect individuals' beliefs about climate change. We also test how these frames affect different partisans in the USA, an important theme given prior work that demonstrates polarization in response to targeted climate change communication efforts.

2 Partisan polarization and climate communication effects

A growing body of work on individual-level framing effects and climate change beliefs shows that exposing citizens to targeted frames can shift opinions toward greater concern about the issue and willingness to take action (for a review, see Bolsen and Shapiro Forthcoming). However, the effects of any message may vary depending on individual-level characteristics such as one's partisan identity (Hart and Nisbet 2012; Kahan 2015), level of open-mindedness (Nisbet et al. 2013), or other factors that may be present in a political context—such as the presence of rhetoric that politicizes climate science (Bolsen and Druckman Forthcoming; McCright et al. 2016; Van der Linden et al. Forthcoming). Survey research conducted in the USA shows that Democrats and liberals tend to be more concerned about climate change, consider it to be more of a threat, and are more willing to support policy action than Republicans and conservatives (Wood and Vedlitz 2007; Zia and Todd 2010). Moreover, targeted messages that may increase concern or mobilize engagement among liberal Democrats may backfire when presented to conservative Republicans (Hart and Nisbet 2012). Hart and Nisbet (2012) explain, "This broad polarization in opinion about climate change is not only due to increase policy polarization in general between the parties... but also due to a specific party divide on environmental issues that has been developing since the 1980s… strong political partisans are likely to employ motivated reasoning when exposed to messages about climate change with ideological predispositions moderating information effects…" (p. 704). We therefore explore whether party identification moderates any effect of the textual or visual frames highlighting sea level rise and its impacts. We anticipate, based on existing research on climate opinions in the USA, that targeted framing effects may produce larger opinion-shifts among Democratic respondents relative to Republican respondents as a result of motivated reasoning in the opinion formation process.

The immediate impact of climate-change driven sea level rise will first affect coastal cities, particularly those with large areas at or near the present sea level. We selected Boston and Miami as examples of such cities susceptible to flooding. Although Miami has been subjected to hurricane-related flooding in the past, Boston is less frequently associated with flood damage. For this reason, participants in the study we describe below could be more accustomed to hearing about flooding in Miami, but less aware of the flooding potential in Boston, which would then be perceived as a relatively novel effect of climate change.

2.1 Data and methodology

Participants To test our proposed hypotheses, we rely on data from an original survey experiment fielded in May of 2017. A total of 729 unique respondents were recruited using Amazon's Mechanical Turk (MTurk). MTurk offers a platform for participant recruitment for use in social science research that is more accessible than random probability samples. While nationally representative, random probably samples are the gold standard, research shows that MTurk samples allow for generalizations beyond the sample, and more so in the context of experimental designs (Mullinix et al. 2015; Levay et al. 2016; Berinsky et al. 2012; Druckman and Kam 2011).

Each participant was randomly assigned to either a pure control condition, or to one of three treatment conditions: (1) the presence of a textual frame that highlights the effects that will occur in US coastal communities as a result of sea level rise due to polar ice melt, and (2) the presence of an additional *animated map* that highlights the amount of sea level rise projected to occur with a 3.5 °F (2 °C) increase in Earth's average temperature in either Boston or Miami. The experiment included four conditions: control ($n = 187$), text only ($n = 178$), text + animated map showing flooding of Boston ($n = 183$), and text + animated map showing flooding of

Miami ($n = 181$) (the Appendix displays the stimulus for each condition, in addition to a description of the geographic distribution of respondents).

Participants in all conditions except the control group were informed that they would read a short article and answer several related questions. The headline that appeared in these conditions, "Rising Sea Levels Will Threaten US Coastal Cities," is followed by a short paragraph that stated:

> Earth's polar ice is melting faster than climate scientists had previously thought because of rising global temperatures. Sea levels rose around the globe in 2016 because of a record low amount of Arctic sea ice. A reduction in ice in Greenland and Antarctica could cause the ocean level to rise by 10 to 15 ft, causing major flooding of coastal cities. In turn, this would result in the loss of many homes and roads, and even the abandonment of entire coastal communities. Even smaller amounts of sea rise could devastate many US coastal cities. For example, just 1 in. of sea level rise equates to about an 8- to 10-ft loss of beach.

Participants randomly assigned to the Boston map or Miami map conditions were exposed to an *additional animated map* showing flooding that will occur in each location as a result of a 15-ft increase in the sea-level due to an increase in Earth's average temperature of up to 3.5 °F (2 °C). We created the animated maps using flood projection images produced by Climate Central's "Surging Seas: Seeing Choices" (see the Supplementary Appendix on how individual projection images were captured at five different points and combined into a single moving graphic that served as the "visual treatment").

We measured how exposure to these frames affected individuals' beliefs about (1) the *perceived impact* of climate change on US coastal communities (extremely positive/extremely negative), (2) *concern* about the effects rising sea levels will have on US coastal communities (extremely unconcerned/extremely concerned), and (3) whether climate change is *occurring* (definitely is not occurring/definitely is occurring). We anticipate that frames highlighting coastal flooding in the USA that will occur as a result of future sea level rise will increase individuals' belief that rising sea levels will have a negative impact on coastal communities (Hypothesis 1), increase individuals' concern about the effects of rising sea levels on coastal communities in the USA (Hypothesis 2), and increase individuals' belief that global warming is occurring (Hypothesis 3). We also assess, given the literature demonstrating varied partisan responses to targeted climate change communication efforts, how Democrats, Republicans, and Independents responded to the experimental treatments across conditions. As mentioned, we anticipate that the frames are likely be impactful across all partisan groups; however, we may observe distinct effects due to existing opinion polarization among partisans and motivated reasoning processes. Finally, given the aforementioned work, we review on the power of visual imagery in shifting opinions and we explore whether exposure to an animated map showing future flooding that will occur as temperatures rise in Miami or Boston increases perceived negative impacts, concern, and belief in climate change beyond what occurs as a result of exposure to the more general textual frame in the absence of an animated map. We include in the supplemental appendix a detailed description of our treatments, survey instrument, and descriptive statistics of the sample.

3 Results

The three research hypotheses were confirmed (Table 1). Respondents exposed to frames in communication highlighting sea level rise and its impact on US coastal cities (1) increased

Table 1 Pairwise Comparison *t* tests of all experimental conditions

Variable	Condition 1: mean	Condition 2: mean	Difference	*p* value
Impact	Control 5.94	Text 6.51	0.57	$p < .01$
Impact	Control 5.94	Boston 6.43	0.49	$p < .01$
Impact	Control 5.94	Miami 6.29	0.35	$p < .05$
Impact	Text 6.51	Boston 6.43	0.08	ns
Impact	Text 6.51	Miami 6.29	0.21	$p < .10$
Impact	Boston 6.43	Miami 6.29	0.14	ns
Concern	Control 4.91	Text 5.25	0.34	$p < .10$
Concern	Control 4.91	Boston 5.39	0.48	$p < .01$
Concern	Control 4.91	Miami 5.08	0.17	ns
Concern	Text 5.25	Boston 5.39	0.14	ns
Concern	Text 5.25	Miami 5.08	0.16	ns
Concern	Boston 5.39	Miami 5.08	0.31	$p < .10$
Occurring	Control 5.68	Text 6.01	0.33	$p < .05$
Occurring	Control: 5.68	Boston 6.05	0.37	$p < .05$
Occurring	Control 5.68	Miami 5.70	0.02	ns
Occurring	Text 6.01	Boston 6.05	0.04	ns
Occurring	Text 6.01	Miami 5.70	0.31	$p < .10$
Occurring	Boston 6.05	Miami 5.70	0.35	$p < .05$

Two-sided *p* values reported above. "Impact" coded so that 1 = "extremely positive" and 7 = "extremely negative;" "Concern" coded so that1 = "extremely unconcerned" and 7 = "extremely concerned;" and "Occurring" coded so that for model 3, 1 = "definitely not occurring" and 7 = "definitely is occurring"

Estimates that failed to reach statistical significance at conventional levels are labeled "ns"

perceptions that sea-level rise will have a negative impact on coastal communities in the USA relative to the control group (Text Only v. Control, diff. = 0.57, $p < .01$; Text + Boston Map v. Control, diff. = 0.49, $p < .01$; Text + Miami Map v. Control, diff. = 0.35, $p < .01$); (2) increased concern about the effects of climate change on coastal communities (Text Only v. Control, diff. = 0.34, $p < .10$); Text + Boston Map v. Control, diff. = 0.48, $p < .01$); and (3) increased belief that global climate change is occurring (Text Only v. Control, diff. = 0.33, $p < .05$; Text + Boston Map v. Control, diff. = 0.37, $p < .05$). The animated map of Miami was marginally less effective than the Boston map in generating concern about the impacts on coastal communities (diff. = .31, $p < .10$) and belief climate change is happening (diff. = .35, $p < .05$).

We present the effects of condition assignment on perceived impact, concern for coastal communities, and belief that global warming is occurring graphically in Fig. 1. Figure 1 displays point estimates of condition means, with error bars representing the 95% confidence

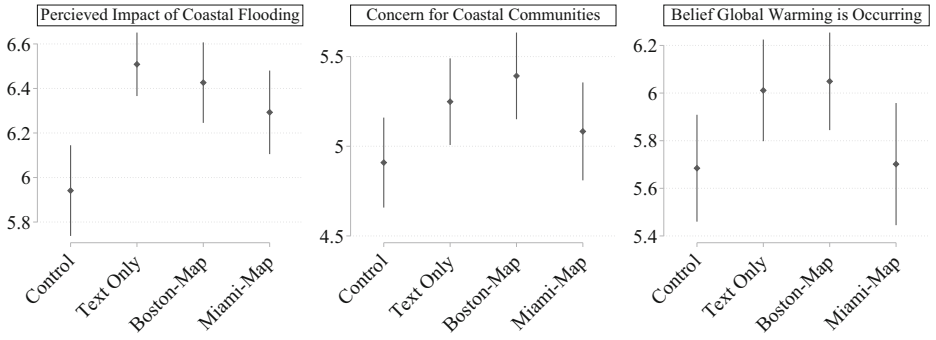

Fig. 1 Experimental treatment effects on dependent measures. Dots represent estimated group means, with error bars representing a 95% confidence interval

interval. Exposure to a textual frame highlighting sea level rise and coastal flooding in the USA as a result of polar ice melt appears to be a strong and impactful communication frame. While we do not find that the animated map produces any significant effect on any of the dependent variables beyond exposure to the textual frame alone, individuals in the Boston map condition reported slightly, but not significantly, higher levels of concern and belief in the existence of global warming relative to the textual frame alone.

In addition to our main analysis, we investigate differences within and across experimental conditions among Democrats, Independents, and Republicans in our sample. A consistent pattern emerges when comparing Democrats, Republicans, and Independents across each of our three key dependent variables (Table 2). As expected, Democrats viewed the impacts of coastal flooding as the most severe, expressed the most concern for coastal communities, and reported the highest levels of belief in global warming compared to Independents and Republicans. This reflects the well-known partisan polarization in the USA on the issue of climate change. More interestingly, the frames generally have a positive effect across partisan groups for each of the key dependent measures. First, we find that perceptions that sea-level rise will have negative impacts on coastal communities increase significantly for Democrats (diff. = .56, $p < .01$), Independents (diff. = .42, $p < .01$), and Republicans (diff. = .89, $p < .01$) in the text only condition compared to the control condition. The substantive impact of exposure to the frame is largest among Republicans in our sample—that is, it shifts this group's perceptions of the negative impacts of climate change on coastal communities almost a full point on our seven-point response scale (see Table A5 in the Supplementary Appendix for standard errors associated with the reported means for each group across dependent variables, 95% confidence intervals, and the *N* for each group per condition). This effect of the textual frame on perceptions of negative impacts persists for Democrats—but not always for Republicans and Independents—when it is presented alongside an animated map of Boston or Miami showing future coastal flooding. Second, in looking at the effect of the frames on concern for coastal communities, the animated map of Boston (in conjunction with the text) significantly increased concern for coastal communities for Democrats (diff. = .34, $p < .05$) and Independents (diff. = .63, $p < .10$) relative to similar individuals in the control condition, but not for Republicans. However, the Miami map (in conjunction with the text) significantly increased concern among Republicans relative to Republicans in the control condition (diff. = .67, $p < .10$), but not for Independents or Democrats. The Miami map (with text) was perceived as significantly weaker than the Boston map (with text) among Independents in our sample both for the dependent measures of concern for coastal communities ((diff. = .58, $p < .10$) and belief climate change is occurring (diff. = .35, $p < .05$)). Third, frames highlighting sea-level rise had a significant effect on belief in the existence of climate change only among Democrats and Independents in our sample. The group means are presented graphically in Fig. 2, with dots representing the estimated means and error bars representing the 95% confidence intervals.

4 Discussion

Persistent flooding caused by global warming is already presenting challenges for many US coastal communities, as demonstrated by hurricane-related damage in Houston, the Florida Keys and Puerto Rico in 2017. There was a consensus among scientists in 2013 that 3 ft of sea level rise was the maximum possible amount by 2100, but many believe 6 to 7 ft may now be

Table 2 Pairwise comparison *t* tests of all experimental conditions

Variable	Condition 1: mean	Condition 2: mean	Difference	*p* value
Democrats				
Impact	Control 6.19	Text 6.75	0.56	$p < .01$
Impact	Control 6.19	Boston 6.79	0.60	$p < .01$
Impact	Control 6.19	Miami 6.58	0.40	$p < .10$
Impact	Text 6.75	Boston 6.79	0.04	ns
Impact	Text 6.75	Miami 6.58	0.17	ns
Impact	Boston 6.79	Miami 6.58	0.20	ns
Concern	Control 5.58	Text 5.70	0.12	ns
Concern	Control 5.58	Boston 6.02	0.44	$p < .05$
Concern	Control 5.58	Miami 5.80	0.22	ns
Concern	Text 5.70	Boston 6.02	0.32	ns
Concern	Text 5.70	Miami 5.80	0.10	ns
Concern	Boston 6.02	Miami 5.80	0.22	ns
Occurring	Control 6.27	Text 6.61	0.34	$p < .05$
Occurring	Control 6.27	Boston 6.60	0.33	$p < .05$
Occurring	Control 6.27	Miami 6.58	0.31	$p < .10$
Occurring	Text 6.61	Boston 6.60	0.01	ns
Occurring	Text 6.61	Miami 6.58	0.03	ns
Occurring	Boston 6.60	Miami 6.58	0.02	ns
Republicans				
Impact	Control 5.46	Text 6.35	0.89	$p < .01$
Impact	Control 5.46	Boston 5.77	0.31	ns
Impact	Control 5.46	Miami 6.16	0.70	$p < .01$
Impact	Text 6.35	Boston 5.77	0.58	$p < .10$
Impact	Text 6.35	Miami 6.16	0.19	ns
Impact	Boston 5.77	Miami 6.16	0.39	ns
Concern	Control 4.00	Text 4.30	0.30	ns
Concern	Control 4.00	Boston 4.36	0.36	ns
Concern	Control 4.00	Miami 4.67	0.67	$p < .10$
Concern	Text 4.30	Boston 4.36	0.06	ns
Concern	Text 4.30	Miami 4.67	0.37	ns
Concern	Boston 4.36	Miami 4.67	0.31	ns
Occurring	Control 4.64	Text 5.09	0.45	ns
Occurring	Control 4.64	Boston 5.04	0.40	ns
Occurring	Control 4.64	Miami 4.80	0.16	ns
Occurring	Text 5.09	Boston 5.04	0.05	ns
Occurring	Text 5.09	Miami 4.80	0.29	ns
Occurring	Boston 5.04	Miami 4.80	0.24	ns
Independents				
Impact	Control 5.98	Text 6.40	0.42	$p < .10$
Impact	Control 5.98	Boston 6.40	0.42	$p < .10$
Impact	Control 5.98	Miami 6.09	0.11	ns
Impact	Text 6.40	Boston 6.40	0.00	ns
Impact	Text 6.40	Miami 6.09	0.31	ns
Impact	Boston 6.40	Miami 6.09	0.31	ns
Concern	Control 4.64	Text 5.33	0.69	$p < .01$
Concern	Control 4.64	Boston 5.27	0.63	$p < .10$
Concern	Control 4.64	Miami 4.69	0.05	ns
Concern	Text 5.33	Boston 5.27	0.06	ns
Concern	Text 5.33	Miami 4.69	0.63	$p < .10$
Concern	Boston 5.27	Miami 4.69	0.58	$p < .10$
Occurring	Control 5.68	Text 5.96	0.33	$p < .05$
Occurring	Control 5.68	Boston 6.02	0.37	$p < .05$
Occurring	Control 5.68	Miami 5.65	0.02	ns
Occurring	Text 5.96	Boston 6.02	0.04	ns
Occurring	Text 5.96	Miami 5.65	0.31	$p < .10$
Occurring	Boston 6.02	Miami 5.65	0.35	$p < .05$

Two-sided *p* values reported above. "Impact" coded so that 1 = "extremely positive" and 7 = "extremely negative;" "Concern" coded so that 1 = "extremely unconcerned" and 7 = "extremely concerned;" and "Occurring" coded so that for model 3, 1 = "definitely not occurring" and 7 = "definitely is occurring"

Estimates that failed to reach statistical significance at conventional levels are labeled "ns"

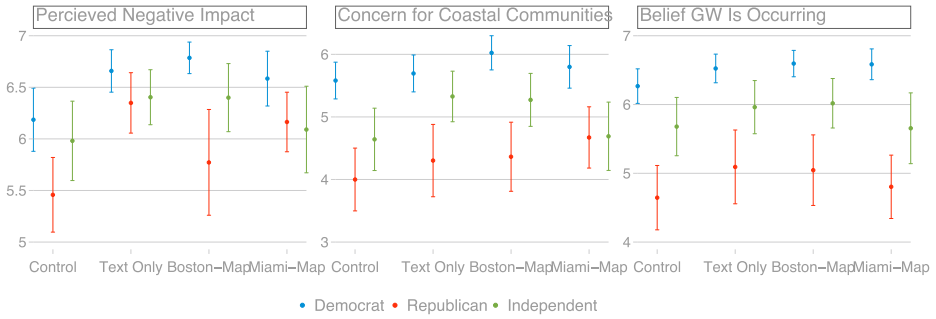

Fig. 2 Partisan differences between conditions for each dependent measure. Dots represent estimated group means, with error bars representing a 95% confidence interval

possible (Gillis 2016). According to Gillis, "A rise that large over a span of decades would be an unparalleled national catastrophe, driving millions of people from their homes and most likely requiring the abandonment of entire cities" (Gillis 2016). Although there is a growing literature that explores emphasis framing and climate change beliefs, our study is novel in that it (1) explores the impact of an understudied, but potentially impactful, frame that accentuates coastal flooding on physically and socially proximate locations; and (2) incorporates visual imagery through the use of animated maps showing future flooding that will result in two major US cities as a consequence of a sustained increase in global temperatures.

We find that individuals who are exposed to such a frame rated the impacts of such flooding to be more severe, increased their concern about flooding that will result from sea-level rise on US communities, and increased their belief in the existence of climate change. Moreover, the frame appears to be impactful not only among Democrats and Independents, but also in some cases among Republicans. In this small experiment, we were unable to test for the impacts of familiarity with or connection to the cities for which the animated maps were presented on responses given the relatively small number of respondents in our sample living in or near these locations (see Table A6 and Fig. 1 in the Appendix for information about the location of participants in our sample). This issue of connectivity is one that merits further research. In addition, we can only speculate about why the animated map of Boston had a greater impact than that of Miami on response. It is possible that the novelty of climate-change related flooding in Boston as compared with the more familiar hurricane-related flooding in Miami had an impact on responses. This too merits further study. Finally, we note that additional research is necessary before we can make firm conclusions about any moderating effect of party identification on the treatments given that we rely on a convenience sample with more Democrats than Republicans compared to the general public.

One goal of climate change communicators is to "inform and educate individuals about climate change, including the science, causes, potential impacts, and possible solutions" (Moser 2010 p.38). This involves searching for new frames of reference that stress climate change's potential for local impacts (e.g., health impacts on vulnerable populations) that can engage new audiences and perhaps resonate across polarized audiences (Maibach et al. 2010). Our findings suggest that frames that accentuate sea-level rise and its impact on US coastal communities may be an effective way to shift fundamental beliefs about climate change. While the "decision lab" is the best place to begin generating evidence-based knowledge about how climate change frames impact audiences, it is critical for future work to move beyond the lab and into the field in order to evaluate their impact on real-world audiences (Kahan and

Carpenter 2017, 310) and on behavioral engagement measures. Levine and Kline (2017) found that accentuating personal food- or health-security risks related to climate change had divergent impacts on individuals' opinions (i.e., *increasing* perceived negative impacts and belief it is happening) and actual behaviors (i.e., *decreasing* willingness to sign a petition or join an advocacy organization). It is thus important to consider not only how frames impact fundamental perceptions and beliefs but also to account for their effects on behavioral engagement. Levine and Kline (2017) explain, "the optimal frames would both increase stated support for climate-friendly policies and also increase people's willingness to spend scarce resources of time, money, and attention communicating that support" (p. 302). Future work is also necessary to make more conclusive determinations about how partisans in the USA respond to the frame we highlight, but we demonstrate that coastal-flooding frames focused on the USA can be impactful across groups that are polarized on climate change.

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