Perceptions of Climate Change in China: Evidence From Surveys of Residents in Six Cities

Jianxun Yang[1,2], Dimitrios Gounaridis[2] , Miaomiao Liu[1] , Jun Bi[1], and Joshua P. Newell[2]

[1]School of the Environment, State Key Laboratory of Pollution Control and Resource Reuse, Nanjing University, Nanjing, China, [2]School for Environment and Sustainability, University of Michigan, Ann Arbor, MI, USA

Abstract China has pledged to cap its carbon emission by 2030 and achieve carbon neutrality by 2060, making knowledge about how the Chinese general public understands climate change crucial and timely. This article reports findings from surveys of climate change perceptions in six Chinese cities (∼40 million people). We identify 10 distinct mental images and 37 subcategories that represent a wide spectrum of perceptions of climate change among the Chinese public. The results reveal that people tend to conflate climate change with air pollution and seasonal weather changes. Although skepticism is not prominent, voices for action are also limited. Furthermore, climate change perceptions are heterogenous across regions and demographic groups. Respondents from developed cities are less likely to conflate climate change with local weather. People living in polluted regions tend to equate climate change with air pollution. Well-educated, high-income, and young residents are more aware of the scientific dimensions of climate change and its consequences. Females and the elderly think more about health implications and how to adapt. Compared to Western countries, opinions about climate change in China are less polarized and controversial, probably due to different political realities and media framings. This study provides an updated picture of climate change perceptions among the Chinese general public and recommends targeted and multi-level communication strategies for policymakers.

Plain Language Summary Understanding how the general public understands climate change is crucial if China is going to achieve ambitious carbon reduction plans. Based on surveys in six cities, this study identifies 10 mental images and 37 subcategories that represent climate change perceptions among the Chinese public. Analyses of mental images reveals that Chinese citizens largely misunderstand climate change as a concept, associating it with changes in local weather patterns and air pollution. This misinterpretation is mainly due to inadequate attention to it and limited information exposure. Compared to Western countries, Chinese citizens are generally less skeptical about climate change, which might be explained by the different political realities and fewer conflicting media framings. Moreover, climate change as a concept has significant geographic and socio-demographic heterogeneity, highlighting the necessity for targeted and regionally-specific information strategies within China. The findings enrich our understanding of how the Chinese public perceives climate change and identifies communication challenges and strategies to increase understanding among the populance.

1. Introduction

Success of climate change initiatives requires concerted social consensus and public engagement at all levels (Lewandowsky et al., 2013), however, climate change perceptions by the general public can vary as a function of demographic, cultural, and ideological factors (Howe et al., 2015; Zhang et al., 2018). Biased views on climate change will constrain policy implementation and exacerbate climate impacts on vulnerable populations (Jenkins-Smith et al., 2020). On this basis, understanding how climate change is interpreted by the lay public is fundamental for policymakers to address this global challenge.

In top emitter countries in North America and Europe, national surveys have been conducted to track the dynamics of public climate change opinion for decades (Egan & Mullin, 2017). For example, the *Climate Change in the American Mind* project revealed that climate change deniers in the United States ranged between 11% and 23% over the last 12 yr (Leiserowitz et al., 2020). Other studies showed that climate change skepticism in the United States peaked between 2006 and 2008 (Egan & Mullin, 2017), declined after the Great Recession in 2008 (Scruggs & Benegal, 2012), and resurged in recent years (Ballew et al., 2019). In Europe, a multi-national survey

documented that the proportion of respondents who ranked climate change as a prominent problem ranged from 38% in Sweden to less than 10% in Eastern and Southern Europe (Farsalinos et al., 2017).

There are also subnational studies highlighting the heterogeneity in climate change opinion across regions and demographic groups. For example, Howe et al. (2015) estimated county-level climate change attitudes in the United States and found a wide range (43%–80%) of how many people had supportive views. A meta-analysis of 25 polls and 171 studies across 56 countries showed that political ideology was one of the most influential determinants of climate change perception (Hornsey et al., 2016). Other important predictors, such as gender, education, and experience of extreme weather events were also investigated but showed mixed results (Bliuc et al., 2015; Boudet et al., 2020). These extensive surveys revealed the challenges in communicating climate change, which further helped to promote more targeted adaptation and mitigation policies in Western countries.

As the world's largest greenhouse gas emitter, China is in a crucial position to change the course of global emissions (Guan et al., 2018). Climate change has risen as one of the top priorities in China (Wang et al., 2019) and the government has already enacted a series of decarbonization policies (Gallagher et al., 2019). However, knowledge about how Chinese people perceive climate change is scarce and geographically limited. Existing surveys are part of cross-national poll projects performed by international agencies, such as Gallup, GlobalScan, and Pew Research Center (Lee et al., 2015; Wang & Zhou, 2020). Most of these outdated surveys were conducted between 2007 and 2010 around the Copenhagen Climate Change Conference. In 2012 and 2017, the China Center for Climate Change Communication (China 4C) released two national-scale climate change awareness reports (Wang et al., 2017). Results from these surveys were ambivalent. For instance, climate change awareness in China accounted for 62% based on the Gallup survey in 2008 (Pugliese & Ray, 2009), 78% based on the BBC Media Action survey in 2010 (Copsey et al., 2014) and 93%–95% based on the China 4C surveys in 2012 and 2017 (Wang et al., 2017).

At the sub-national level, studies mostly focused on single cities or were limited to specific population groups with relatively small samples (Jamelske et al., 2015; Shi et al., 2019; Winden et al., 2018). For example, Yu et al. (2013) used 237 online questionnaires to measure public climate change perceptions in Beijing but over 80% of their respondents were college students, and thus not representative of the entire society. Insufficient knowledge about how the Chinese general public understand climate change impedes targeted policy efforts to communicate climate change risks and engage the public into behavioral changes.

Regarding the survey methodology, previous studies are often based on binary Yes-No or Likert-type scaled questions. While these closed questions help record public opinion, they fail to capture the diversity of individual conceptualization and respondents with no opinion might answer anyway. This will likely lead to false estimates and will blur the overall picture, since studies have reported that the Chinese public might not fully apprehend what climate change is but present supportive views on related policies (Wei et al., 2014).

By contrast, open-ended survey methods are advantageous in interpreting how climate change is felt and understood by the general public. Researchers have used such qualitative methods to study perceptions on climate change since the early 1990s. For example, Kempton (1991) interviewed a small sample of US residents and found that the general public interpreted climate change based on pre-existing concepts, such as plant photosynthesis and tropospheric pollution. After the 2000s, mental image association has become a popular open-ended survey tool to investigate climate change perceptions (Wang et al., 2018). According to the dual process theory, when interpreting unfamiliar or abstract concepts like climate change, people are likely to apply heuristic functions and refer to existing knowledge or experiences (Leviston et al., 2014). This process produces mental images, which represent how one perceives vague concepts. Formation of climate change mental images is affected by many factors, such as the imageries that prevail in mass media and personal experiences with extreme events (Leviston et al., 2014; O'Neill et al., 2015). Thus, mental images related to climate change offer a unique lens to observe the diverse concepts revolving around this topic in people's minds.

Many researchers have deployed elicitation tasks to retrieve climate change mental images. These studies are based on open-ended surveys (field or online), which allow respondents to use their own frame of reference. Then, using manual coding or text analysis, random answers are summarized into several topics, which concisely represent the wide spectrum of climate change perceptions. For example, an early work by Leiserowitz (2006) examined mental images of Americans and found 24 distinct images including "melting ice," "heat," "ozone depletion," and "flood/sea level." In Australia, Leviston et al. (2014) identified a total of 215 distinct image categories
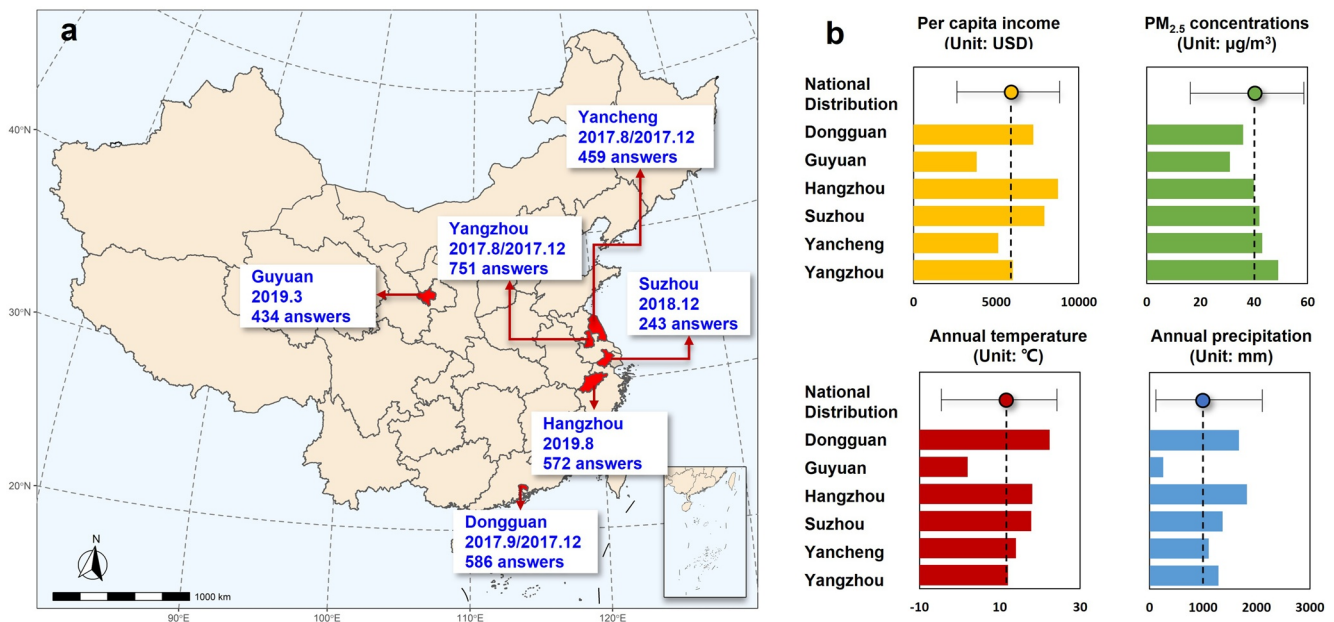
Figure 1. Survey process and city information. (a) Location of cities, date of interviews, and valid responses received from each city. (b) Income, air quality, and climatic conditions of each city and their comparisons with national distribution. All data are available from China's Statistical Yearbook 2018.

of which "rising sea level," "melting ice," and "drought" were the top picks among respondents. Tvinnereim and Fløttum (2015) parsed thousands of open-ended answers from Norwegian citizens and identified four distinct topics, including "weather/ice," "future/impact," "money/consumption," and "attribution."

This study aimed to understand how the Chinese general public perceive climate change by analyzing their mental images generated when introduced to this concept. Over a 2-yr period (August 2017–August 2019), we conducted field surveys in six Chinese cities reflecting a total population of ~40 million. We applied mental image association tasks and collected open-ended answers from a large cohort of respondents across the cities. 10 categories and 37 subcategories of distinct mental images covering broad topics were identified with manual coding. Using content analysis and logistic regression modeling, we answered the following three questions: (a) Which climate change mental images are prevalent among the Chinese public? (b) How do Chinese climate change mental images differ across regions? (c) How does the socio-demographic heterogeneity contribute to the diversity of climate change mental images?

2. Materials and Methods

2.1. Survey Design

We designed a multiple-rounds survey with in-person interviews from August 2017 to August 2019, in six cities of China: Dongguan, Guyuan, Hangzhou, Yancheng, Yangzhou, and Suzhou, respectively. We included cities spanning a range of development levels, environmental quality, and local climate to capture regional heterogeneity. Figure 1a illustrates the city location, date of interviews, and number of responses. Figure 1b illustrates the variation captured by the six cities in terms of development, climate, and environmental quality.

In China, the level of economic development varies across regions. Developed cities have better access to urban infrastructure and educational resources, which are associated with climate change awareness and knowledge (Hornsey et al., 2016). Using per capita income as a proxy, the six chosen cities cover a wide spectrum of economic realities ranging from 3,800 (Guyuan) to 8,700 (Hangzhou) US dollars. In addition, we used annual average concentration of particulate matter ($PM_{2.5}$) to indicate urban air quality, since people might conflate environmental problems with climate change (Fleming et al., 2021). In general, cities on the eastern coast with heavy industries suffer more severe pollution (e.g., Suzhou: 44 µg/m³) while others in the mainland have lower $PM_{2.5}$ concentrations (e.g., Guyuan: 30 µg/m³). Moreover, climate change perception is affected by local climate (Howe

et al., 2019). Our sample captures a large variation in terms of average temperature and precipitation ranging from the northern dry and cold regions (Guyuan: 256.3 mm; 4°C) to the southern humid and warm coastal cities (Dongguan: 1,827 mm; 22.4°C).

To ensure fully representative sampling, we collaborated with local coordinators to recruit participants. We grouped the population of each city per gender, age, education, and income level and devised a stratified sampling process. Participants were randomly recruited from each group and provided payments as incentive. The authors visited each city to have face-to-face interviews. Verbal consent was received from participants. An open-ended question was asked to each participant: *What are the first three images or concepts that come to your mind when hearing "climate change"?* This question followed a typical design of image association task (Leviston et al., 2014; Tvinnereim & Fløttum, 2015). Up to three answers were collected from each participant. A total of 1,181 respondents participated in our project, and we collected 3,045 valid answers.

Socio-demographics including gender, age, education level, and family income were also collected from each respondent. In addition, we asked three questions to understand how the respondents perceived climate abnormalities: (a) *"How do you compare recent winter climate to ten years or earlier?"*; (b) *"How do you compare recent summer climate to ten years or earlier?"*; (c) *"How does recent frequency of extreme weather events compare to ten years or earlier?"*. We assigned one point for each question if respondents felt warmer winter, hotter summer, and more frequent extreme weather. The highest score for each participant's climate anomaly perception was 3 while the lowest was 0. See descriptive statistics of answers in Table S1 in Supporting Information S1.

2.2. Mental Image Coding

After reviewing existing climate change coding schemes focusing on Western countries (Ogunbode et al., 2019; O'Neill et al., 2015; Tvinnereim & Fløttum, 2015), we realized these frameworks did not fully reflect the answers from the Chinese general public. Accordingly, we developed a new coding scheme through an inductive process. We derived topics, including *disaster*, *health,* and *weather*, from Smith and Leiserowitz (2012) and Tvinnereim et al. (2017) as the basic image coding scheme. We manually reviewed the answers and when there were prevalent answers outside the existing coding scheme, we added supplemental images, such as *temperature* and *pollution*. Each image was also broken down into subcategories. For example, *typhoon, flood*, and *drought* were subcategories of *disaster*. The final scheme consists of 10 mental images and 37 subcategories. Based on that, two researchers independently assigned each answer into one of the mental image categories and subcategories. After manual coding, we compared the independent coding schemes of two researchers and calculated a Cohen's kappa score of 0.95, which indicated good agreement of the manual coding process. Lastly, ambivalent answers and conflicted coding results were discussed in group meetings and assigned into a single category.

The final coding scheme exclusively summarizes all the answers, as shown in Table 1. The 10 mental images covered broad topics including manifestations and implications of climate change (*weather*, *temperature*, *disaster*, *health*, and *socio-economic impact*), related abstract scientific concepts (*scientific term*), environmental issues (*pollution*), potential solutions (*mitigation* and *adaptation*), and anthropogenic causes (*cause*). Most images had three to four subcategories. One exception was *disaster*, for which we identified more than 10 distinct types.

2.3. Data Analysis

To statistically examine the geographic and socio-demographic heterogeneity, we fitted a logistic regression model using the *lme4* package in R (Bates et al., 2015). The equation is specified as follows:

$$IMAGE_i = \beta_0 + \beta_1 GEN_i + \beta_2 AGE_i + \beta_3 EDU_i + \beta_4 PER_i + \beta_5 INC_i + \beta_6 CITY\_ECO_i + \beta_7 CITY\_PM_i + \beta_8 CITY\_TEMP_i + \varepsilon_i, \tag{1}$$

The dependent variable $IMAGE_i$ is a dichotomous variable where 1 is the value when the participant associates the ith mental image. We used nine mental images *weather*, *temperature*, *pollution*, *disaster*, *scientific term*, *health*, *adaptation*, *cause*, and *mitigation* as dependent variable, respectively, which produced 9 logistic models. We excluded *socio-economic impact* due to its limited answers.

Eight independent variables were considered in the model. Gender (*GEN*), age (*AGE*), education (*EDU*), family income (*INC*), and climate anomaly perception (*PER*) were five individual-level demographics. *CITY_ECO*,

Table 1
Overview of the 10 Mental Images and 37 Subcategories

Mental images	Count and proportion	Brief description and subcategories
Weather	656 (22%)	Daily or seasonal changes of weather conditions. Four subcategories.
		(1) Bad weather: rain, snow, gale, etc.
		(2) Nice weather: sunny, sunshine, etc.
		(3) Old proverb without strong causal relationship with climate change
		(4) Meteorological terms: monsoon, season, air pressure, etc.
Temperature	559 (18%)	Description of temperature experience. Four subcategories.
		(1) Hot images: heat, hot, warm, etc.
		(2) Capricious: sudden and unpredictable temperature, etc.
		(3) Anomaly: hotter summer, warmer winter, etc.
		(4) Cold images: chill, cold, etc.
Pollution	473 (16%)	Environmental pollution and ecological degradation caused by human activities. Three subcategories.
		(1) Air pollution: $PM_{2.5}$, smog, haze, and so on
		(2) Other types of pollution: water pollution, chemicals, noise, solid waste, and so on
		(3) Degradation: deforestation, soil erosion, and so on
Disasters	382 (13%)	Extreme weather events or dreadful natural disasters. A total of 11 subcategories.
		(1) Hurricane
		(2) Sandstorms
		(3) Melting ice
		(4) Flood
		(5) Rising sea
		(6) Earthquake
		(7) Drought
		(8) Hail
		(9) World endings
		(10) Wildfire
		(11) Others
Scientific terms	292 (10%)	Well-established scientific concepts. Three subcategories.
		(1) Global warming
		(2) Greenhouse effect
		(3) El Nino and ozone hole
Health	205 (7%)	Public or individual health threats. Three subcategories.
		(1) Pandemic or diseases: flu, heatstroke, pharyngitis, cough, infectious diseases, and so on
		(2) Physical discomfort: stuffy, dull, and so on
		(3) Unhappy: agitated, annoyed, and so on
Adaptation	200 (7%)	Self-protective measures. Four subcategories.
		(1) re. Temperature change: keep warm, wear more clothes, and so on
		(2) re. Weather change: take umbrella, read the weather forecast, and so on
		(3) re. Air pollution: wearing masks, stay at home, and so on
		(4) Others: prevent, more exercise, and so on

Table 1
Continued

Mental images	Count and proportion	Brief description and subcategories
Cause	124 (4%)	Causes of global climate changes. Three subcategories.
		(1) Vehicles or industrial emissions
		(2) Urbanization or economic development: urban land use, improvement of living standard, and so on
		(3) CO_2/fossil fuel burning
Mitigation	124 (4%)	Solutions or actions against climate change. Two subcategories.
		(1) Emissions reduction: energy saving, reduce GHG emissions, Paris Agreement, collective response, and so on
		(2) Protect environment: planting trees, protect nature, and so on
Socioeconomic impact	30 (1%)	Climate change impacts on daily life or macro-economics, such as affecting traffic, affecting daily life, economic impacts, food security, energy crisis, and so on

CITY_PM, and *CITY_TEMP* were three numeric city-level geographical covariates measuring the per capita income, particulate matter concentrations and average annual temperature in each city, respectively. These variables reflect the development levels, environmental quality, and local climate of each city, which are known to influence climate change perceptions.

3. Results

3.1. Confusion of Key Concepts Among Respondents

We find the majority of respondents (80%) have a narrow perspective of what climate change is, as they generate mental images bounded within five main topics (*weather*, *temperature*, *pollution*, *disaster*, and *scientific term*) when asked about it (Table 1). Respondents' mental images are also revolving around a limited number of subtopics (Figure 2). Rainy or cold weather, air pollution and high temperature, as the top three subcategories, are all related to local micro-climatic and environmental changes and are not directly related to climate change. Those three sub-images account for about one third (33.8%) of all the answers when combined. Unbalanced proportions of mental images show that respondents fail to grasp the full spectrum of climate change externalities.

Our results also show a large proportion of respondents confuse climate change with local weather changes and environmental pollution, which is alarming and highlights the need for effective communication strategies. Many respondents struggle to form concrete mental images due to insufficient knowledge. See representative responses in Table S2 in Supporting Information S1. For *weather* images, most respondents interpret climate change as daily weather conditions, such as rain, snow, and sunlight (sub-images *bad weather* and *nice weather* >86% when combined). Some seniors come up with old Chinese weather proverbs (sub-image *proverb*, 7%), which are conceptually unrelated to climate change. In terms of *temperature*, most answers simply describe thermal comfort (sub-image *hot* and *cold* together 62%). For sub-image *capricious*, responses are complaints about seasonal rapid temperature changes (20%). Only a few people (sub-image *anomaly*, 18%) point out abnormal temperature trends, such as extreme heat and warmer-than-average winters as being related to climate change. People who confuse these concepts might lack motivation for behavioral change.

Popularity of the *pollution* is remarkable among the respondents. Confusion of this concept shows that Chinese people are aware of environmental issues and encourage future mitigation efforts however they fail to recognize the synergies of these concepts, how they are related and to what extent. Specifically, *air pollution* is the most dominant sub-image (71%) and particulate matter (PM) is the most prevalent pollutant that people come up with. Water pollution, industrial pollution, solid waste as well as noise are occasionally mentioned (24%). Moreover, only 5% of respondents associate environmental degradation such as habitat destruction and wildlife extinction with human activity.

Confusion is also evident in less popular images. When respondents generate mental images of *adaptation*, most answers (65%) are related to short-term and self-protective measures against local weather variations and air
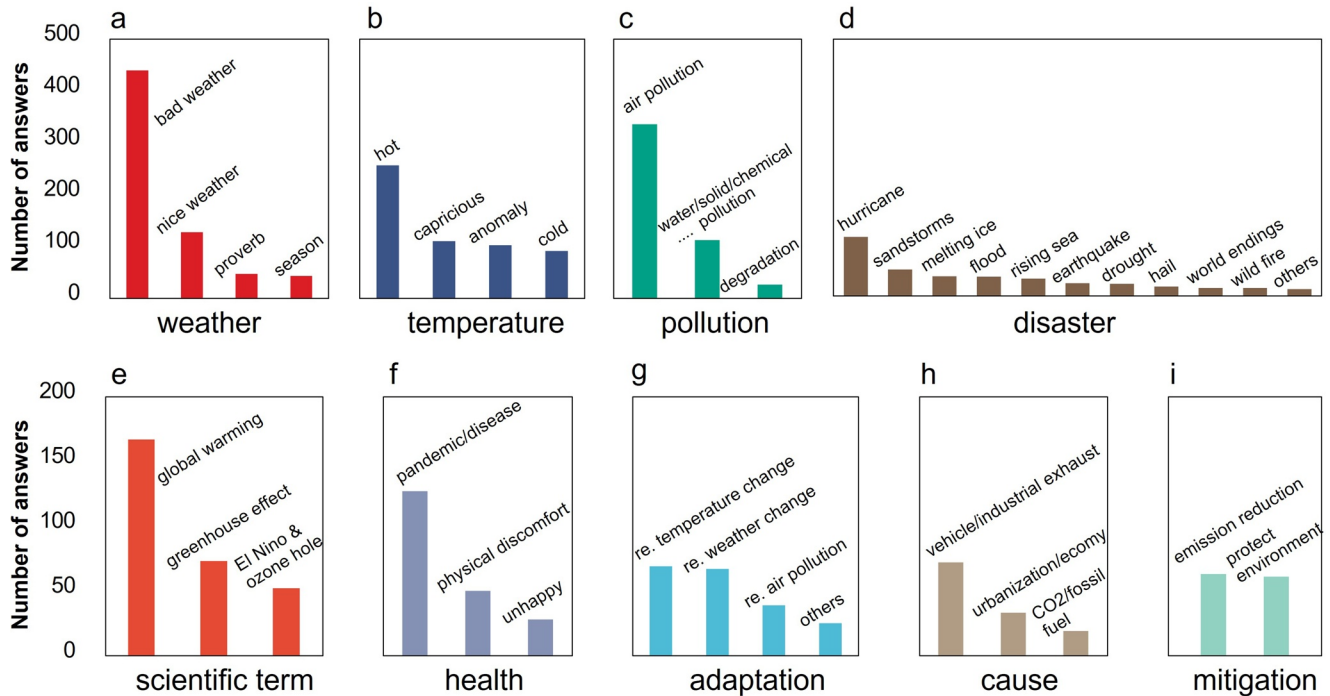
Figure 2. Subcategory mental image prevalence. Bar charts represent the number of answers for each subcategory.

pollution. Moreover, for the mental image *cause*, 58% of respondents attribute climate change to industries or traffic emissions without clearly recognizing the key role of GHG emissions driven by demand, consumption patterns and lifestyles. Lastly, the Chinese public have a broad sense of climate-related events (*disaster*). For instance, typhoon is one of the most well-known extreme weather events, taking up a significantly high proportion (30%) of responses.

3.2. Less Skepticism but Limited Voices for Action

Our analyses reveal that climate change skepticism is less prominent in China. For instance, *scientific term* ranks in the top five popular topics and *global warming* and *greenhouse effect* are the most recognized sub-images (combined >87%). We do not find any answers that dismiss the existence of climate change. Despite the relatively low representation of climate change skeptics, voices for collective actions are still limited. Responses assigned in *mitigation* and *cause* account for less than 10% when combined. Even though more than half the answers (51%) in *mitigation* point out emission-reductions and energy-savings, none of them could pin down who is responsible for meeting the mitigation targets. This indicates that people in China do not have a clear picture of the synergistic relationship between governmental regulations and individual behavioral changes.

3.3. Geographic and Socio-Demographic Heterogeneity

Mental image prevalence varies dramatically per city as illustrated in Figure 3. Table 2 presents the statistical test results of three city-level predict.

The popularity of *weather* is significantly associated with the city's development level as indicated by the per capita annual income. In the three least developed cities (Guyuan, Yancheng, and Yangzhou), the *weather* mental image is picked by 25% of respondents. People in developed cities (Hangzhou and Suzhou) are less likely to confuse climate change with micro-climate patterns probably due to higher rates of educated people.

Our results show that confusion between climate change and *pollution* is widespread nationally. The *pollution* mental image ranks in the top five most popular mental images among all the surveyed cities and is positively correlated with the actual $PM_{2.5}$ concentration level of each city. In general, *pollution* shares slightly larger

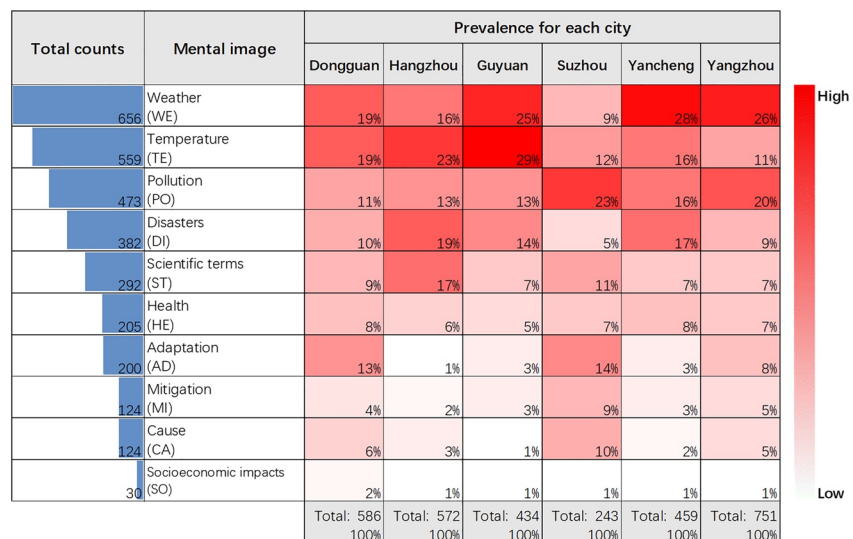| Total counts	Mental image	Prevalence for each city					
		Dongguan	Hangzhou	Guyuan	Suzhou	Yancheng	Yangzhou
656	Weather (WE)	19%	16%	25%	9%	28%	26%
559	Temperature (TE)	19%	23%	29%	12%	16%	11%
473	Pollution (PO)	11%	13%	13%	23%	16%	20%
382	Disasters (DI)	10%	19%	14%	5%	17%	9%
292	Scientific terms (ST)	9%	17%	7%	11%	7%	7%
205	Health (HE)	8%	6%	5%	7%	8%	7%
200	Adaptation (AD)	13%	1%	3%	14%	3%	8%
124	Mitigation (MI)	4%	2%	3%	9%	3%	5%
124	Cause (CA)	6%	3%	1%	10%	2%	5%
30	Socioeconomic impacts (SO)	2%	1%	1%	1%	1%	1%
		Total: 586 100%	Total: 572 100%	Total: 434 100%	Total: 243 100%	Total: 459 100%	Total: 751 100%

Figure 3. Proportion of mental images received per city. Deeper red indicates higher prevalence.

proportions among eastern coastal cities where environmental issues are more evident (e.g., Suzhou, 21% and Yangzhou, 20%). By comparing the relative prevalence of the sub-image *air pollution*, we find more pronounced disparities across cities (Figure S1 in Supporting Information S1). For developed coastal cities such as Suzhou, 91% of answers are about poor air quality or specific air pollutants such as $PM_{2.5}$ and ozone. In cities far from the eastern coast with better air quality such as Dongguan, only 50% of answers are about air pollution.

Despite the general popularity of *temperature* as a mental image, we find people living in cold places are more sensitive to temperature anomalies. As shown in Figure S2 in Supporting Information S1, local annual average temperature is negatively correlated with the prevalence of sub-image *anomaly*. For instance, people living in Guyuan, the coldest city in our study, are more aware of abnormal climate trends compared to the residents in Dongguan who are exposed to higher temperatures. Furthermore, people from cities with better economy, more severe pollution, and warmer climate show lower likelihood of associating *disaster* but higher likelihood of associating *adaptation*, *mitigation*, and *cause* with climate change.

In addition, heterogeneity within cities is influenced by demographic factors. People with different socio-economic backgrounds interpret climate change from diverging angles. Gender significantly affects the prevalence of *disaster*, *health*, *adaptation*, and *cause* (Table 2). Specifically, females are more likely to come up with *health* and *adaptation* related images, while males tend to point out the *cause* and *disaster* of climate change. Prevalence of *health and adaptation* among females show they have higher risk perceptions facing the uncertain health impacts of climate change and think more about self-protection. Instead, males think more about the disastrous consequences and how to control the risks.

Age moderates the tendency to associate *scientific term* and *adaptation*. Seniors think more about the adaptive strategies while younger respondents are more likely to raise abstract scientific terms and they also recognize terminology, such as global warming and greenhouse gases. This discrepancy reflects the generation gap in terms of social vulnerability and worldviews in a fast-growing and transitional economy like China. The aged groups are in general less educated than the younger and thus most of them are unfamiliar with climate change and worried more about the impact of unknown risks.

Our model suggests education is one of the strongest predictors. Higher education correlates with higher prevalence of *pollution*, *disaster*, and *scientific term*, indicating that educated citizens are more familiar with the disastrous manifestation and scientific consensus of climate change. The model also suggests higher family income predicts lower prevalence of *weather* but higher prevalence of *health* mental images. It shows that people with higher income are less likely to confuse climate change with local weather.

Table 2
Logistic Regression Estimates in Exponentiated Odds Ratios With Standard Errors

Predictors	Weather		Temperature		Pollution		Disaster		Scientific term		Health		Adaptation		Mitigation		Cause	
	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE
INTERCEPT	0.18	0.29	-1.66***	0.32	-2.67***	0.34	-2.72***	0.38	-3.28***	0.43	-2.11***	0.46	-3.65***	0.50	-2.95***	0.59	-2.79***	0.57
GEN	0.16	0.09	-0.08	0.11	-0.05	0.11	0.32**	0.12	0.01	0.13	-0.69***	0.17	-0.50**	0.16	0.05	0.20	0.55**	0.19
AGE	-0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	-0.02***	0.01	0.01	0.01	0.03***	0.01	0.00	0.01	0.01	0.01
EDU	-0.08*	0.03	-0.05	0.03	0.11**	0.04	0.11**	0.04	0.23***	0.05	-0.22***	0.05	0.05	0.05	-0.07	0.07	-0.20**	0.06
PER	-0.16**	0.05	-0.07	0.06	0.10	0.07	0.16*	0.07	0.14	0.08	0.00	0.09	-0.09	0.09	0.06	0.12	0.00	0.11
INC	-0.09*	0.04	0.05	0.04	0.03	0.05	-0.07	0.05	0.05	0.05	0.17**	0.06	-0.10	0.07	0.02	0.08	-0.01	0.08
CITY_ECO	-0.38***	0.08	0.06	0.08	0.07	0.08	-0.19*	0.09	0.14	0.10	-0.07	0.12	0.47**	0.14	0.25	0.15	0.61***	0.15
CITY_PM	-0.02	0.22	-0.12	0.15	0.55***	0.14	-1.03***	0.16	-0.16	0.18	-0.06	0.20	1.75***	0.30	1.12***	0.27	1.26***	0.30
CITY_TEMP	0.00	0.12	-0.18	0.22	0.24	0.13	-0.91***	0.14	-0.21	0.16	0.06	0.19	1.93***	0.29	0.85**	0.27	1.11***	0.29
R² Tjur	0.036		0.019		0.019		0.028		0.038		0.018		0.059		0.009		0.030	

Note. Reference category for GEN (1 = male). *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$. β coefficients indicate probability of associating the corresponding image.

4. Discussion

4.1. Cross-National Comparisons of Climate Change Mental Images

We compare our results with several open-end survey studies in Western countries (Table 3). We find climate change conceptualizations across countries align in certain aspects but have more differences.

First, *weather* and *temperature* are popular associations in people's mind both in Western countries and in China. In European countries like UK and Norway, weather is the most prominent climate change association (Lorenzoni & Pidgeon, 2006; Tvinnereim & Fløttum, 2015). In the United States, respondents are more concerned about the rising temperature (Smith & Leiserowitz, 2012). Although *weather* is a prevalent mental image across countries, people have different misconceptions toward weather and climate change. In the United States, climate change skeptics claim extreme cooling weather as evidence against global warming, which indicates confusion of short-term changes in local temperatures with the long-term changing climate across the globe (McCaffrey & Buhr, 2008). As indicated by the *natural cycle* mental image, some acknowledge climate change but believe it is natural and inevitable, overlooking the anthropogenic causes. They also conflate weather variation and climate and discuss them synonymously (Fleming et al., 2021; Higginbotham et al., 2014; Leviston et al., 2014). In China, however, based on our results, people who confuse climate change with weather are simply uninformed and have no intension or interest to challenge the scientific consensus of climate change. In fact, for a large proportion of the Chinese general public, climate change is not a hot-debated problem, or at least not one that receives much public attention, let alone controversy. This points to the necessity of extensive information campaigns to inform the public about the explicit short and long-term implications of climate change and the behavioral changes required to reach the GHG emission reduction targets.

Second, we notice that *pollution* is also a top mental image in the West. Ozone depletion used to be a representative image of climate change for US and UK citizens. At that time, global warming was regarded as a subset of stratospheric ozone depletion by the general public (Kempton, 1991). In more recent years the ozone hole shrank and the topic eventually lost momentum, and so did the prevalence of ozone as a mental image in more recent surveys (Smith & Leiserowitz, 2012). In China, about 16% of answers in our study equate climate change with local pollution. From all the pollution-related answers, particulate matter (PM) is the most frequently mentioned pollutant. Since the 2013 smog crisis, PM pollution has been on the social spotlight in China (Yang et al., 2018). This in turn seems to be a driver of this strong connection between climate change and pollution. Individuals who link air pollution to climate change are generally more supportive on mitigation policies. This could, however, lead individuals to believe that climate change can be fixed easily with a few policy regulations and a stricter legislative framework on industrial emissions.

Third, many studies in Western countries report high rates of mental images on climate change skepticism and/or denialism, which reflect a general dichotomy of climate change realization. In contrast, we find no evidence of skepticism and/or denialism in China. Educated young people in China think of climate change more as a scientific concept than an international challenge, and there is no polarization of opinions. Yet we also notice some seniors and less educated people from less developed regions in China have a blurred view of climate change. In this regard, limited opposing voices from these groups do not necessarily reflect a societal consensus rather than inadequate information exposure and lack of background knowledge.

Finally, some stereotypical images, such as melting ice, polar bears, rising sea-level are less prevalent among the Chinese lay public. In contrast, these images are typical media

Table 3
Cross-National Comparison of the Top Prevalent Climate Change Mental Images

Citation	Country	Sample size (n)	Survey period	Survey methods	Research design	Top mental images in descending order of prevalence
Kempton (1991)	USA	14	1990	Face-to-face interview	**Question:** *"What have you heard about greenhouse effect/global warming/climate change?"* Verbatim transcript of the interviews was made. Statements from respondents were summarized by the author.	(1) Ozone depletion; (2) Air pollution; (3) Photosynthesis; (4) Experienced temperature variation
Lorenzoni et al. (2006)	UK	318	2002	Face-to-face interview	**Question:** *"Which three things, if any, come to your mind when you hear the phrase 'climate change'?"*. Answers were categorized based on an existing coding scheme.	(1) Weather; (2) Global warming; (3) Ozone; (4) Changing climate
Lorenzoni et al. (2006)	USA	673	2002–2003	Mail survey	**Question:** *"What is the first (second, third) thought or image that comes to your mind when you think of 'global warming?'"*. An inductive content analysis was then performed by two coders to reduce the data into 29 thematic categories.	(1) Ice melting; (2) Heat; (3) Nature; (4) Ozone; (5) Disasters; (6) Skepticism
Smith and Leiserowitz (2012)	USA	1,001	2010	Telephone interview	**Question:** *"When you think of 'global warming,' what is the first word or phrase that comes to your mind"*. A total of 24 categories were finally coded based on the codebook developed by authors.	(1) Naysayers; (2) Alarmist; (3) Ice melting (4) Heat; (5) Weather
Connor and Higginbotham (2013)	Australia	467	2011	Telephone interview	**Question:** *"Would you like to make any further comments about climate change, or any other issue related to this interview?"*. Responses are independently coded by two researchers using basic qualitative analysis. Four main themes emerged through coding.	(1) Natural cycles; (2) Skepticism; (3) Government actions; (4) Believer
Leviston et al. (2014)	Australia	2,502	2010	Online survey	**Question:** *"What are the first 3 images that come to mind when you think about climate change?"*. Answers were manually coded, and 82 actual images were compiled.	(1) Rising sea levels; (2) Drought; (3) Melting ice; (4) Floods; (5) Pollution
Tvinnereim and Fløttum (2015)	Norway	2,115	2013–2014	Online survey	**Question:** *"What comes to mind when you hear the words 'climate change'?"*. Structural topic modeling was applied to yield distinct topics based on relative frequencies of the words in open-ended responses.	(1) Weather/Ice; (2) Future/Impact; (3) Consumption; (4) Attribution
Fleming et al. (2021)	USA	77	2016–2017	Telephone interview	**Question:** *"What comes to mind when you think of climate change?"*. Focus on causal misconception of climate change. All interviews were manually coded using a hierarchical coding scheme.	(1) Natural variability; (2) Air pollution; (3) Carbon emission; (4) Ozone depletion; (5) Greenhouse gas
The present study	China	1,181	2017–2019	Face-to-face interview	**Question:** *"What are the first three images or concepts that come to your mind when hearing the word "climate change".* Answers were manually coded following the scheme developed by the authors.	(1) Weather; (2) Temperature; (3) Pollution; (4) Disasters; (5) Scientific terms

representations of climate change in Western countries and as a result they score high in open-ended imagery surveys (Smith & Leiserowitz, 2012). Recent studies show that such images appear to reinforce perceptions that climate change is a distant, long-term issue and thus they reduce perceived salience (O'Neill et al., 2013), or sometimes they even cultivate cynicism and denialism (Chapman et al., 2016).

In terms of the geographic and demographic heterogeneity, our study shows that most existing theories and findings in the West also hold true for Chinese people. For example, previous studies have recognized gender as an important factor affecting climate change perception (Poortinga et al., 2019; Weber, 2016). Some suggest that males perceive less hazard risk because of their dominant role in controlling and benefitting from technology (Finucane et al., 2000). Our study confirms the gender difference in conceptualizing climate risks and find that females are more concerned about the health impacts of climate change. We also find city economic level, family income, and education are key predictors of climate change mental images in China, which is aligned with the results given by Lee et al. (2015).

4.2. Drivers and Implications of Climate Change Mental Images

Climate change mental images in the Chinese mind might be shaped by a range of factors, such as political reality, media coverage, and education. According to the theory of social identity, people generate their opinions largely affected by elite cues or credible messengers from their own social and political groups (Bullock, 2011). In Western countries, the partisan divide keeps growing and shapes polarized public opinion on social issues including climate change (Dunlap et al., 2016). Climate change has long been a hot social topic and a persistent segment of population in the West hold skeptical views toward climate change. Conservative-leaning ideology is one of the key predictors of climate change denials (Hornsey et al., 2018). In China, the government leads the narratives along with the policies and agendas for each societal challenge. Different political reality may explain why opinion polarization regarding climate change is less prominent in Chinese contexts.

The media environment is another potential driver of the formation of climate change opinion. The Construal Level Theory suggests that psychological distant concepts like climate change are usually represented by high-level and abstract concepts and heavily determined by media exposure (Liu et al., 2021; Maiella et al., 2020). The Chinese media coverage of climate change focuses on environmental and human impacts but is hesitant to include any conflicting views (Han et al., 2017), as it happens daily in Western countries (Gustafson et al., 2019). Therefore, the Chinese people are less likely to get exposed to opposing views on climate change and partly explains why skepticism or denialism are not prominent among the Chinese lay public. In addition, the climate change agenda in Chinese media revolves around the responsibilities among China and other developed countries and they emphasize the need to achieve a balance of economic development while addressing climate change (Xie, 2015). Those framings do not feel relevant at the individual or household level and might explain why people are unaware of the individual behavioral changes needed to address climate crisis. Education might also play an important role in forming climate change perceptions. Our study shows that confusion with local micro-climate is prevalent in less developed regions and among seniors as well as lower income groups who are less educated, but also more vulnerable. Misconception of climate change among the less educated populations might constrain their motivations for engagement.

Our results have practical implications and here we recommend several targeted strategies to promote public engagement. First, popular media outlets should be incentivized to help people realize personal relevance and immediacy on the climate change issue. This can be achieved by targeting local communities and specific socio-demographic groups. Science informed media outlets can aid in these goals by presenting science-driven facts and by filtering-out or even-better demystifying false-equivalencies. Second, we recommend multi-level communication campaigns to increase engagement of the lay public to climate change. It is crucial for those campaigns to be tailored according to the unique context of each region and population groups (Shwom et al., 2010). Climate change should be introduced in public education universally across the country, facilitating individual and social learning at all schooling levels. Third, our results also show that a fraction of the Chinese population might incorrectly equate climate change with local air pollution. To tackle this misconception, science-informed strategies should not only highlight the synergies between the two but also delineate their different concepts, ramifications, and externalities. Nevertheless, the psychological link between the two issues should be leveraged. For example, policymakers should deliver concrete messages that curbing industrial or vehicle emissions facilitates pollution reduction and climate change mitigation in tandem.

4.3. Strengths and Limitations

This study makes the following contributions. First, we report the most updated sub-national climate change perceptions in China based on open-ended questions. We highlight the differences in public views between China and Western countries and provide theoretical explanations. For future research, open-ended survey method has the potential to add to the existing research framework of climate change opinion. For example, the open-ended method allows free expression of ambiguity and uncertainty of climate change, which can be used to explain the results from traditional opinion surveys. Researchers can also ask respondents to think what climate change is and choose from a range of mental images built upon this study and others. Second, through multi-city and multi-group comparisons, we show the geographic and socio-demographic heterogeneity in climate change conceptualization across the country, which remains unexplored in Chinese context. The results underscore the importance of nuanced views on climate change opinion at the sub-national level and highlight the need for an effective communication strategy. Such knowledge is crucial for policymakers to implement climate policies and engage the public at all jurisdictional levels.

Several limitations should be acknowledged in our study. First, the survey is based on face-to-face interviews, and thus there is an inherent geographical constraint. Given that we are not able to conduct in-person interviews and achieve full coverage of cities across the country, we instead select cities across a range of development levels, environmental qualities, and climates to capture the heterogeneity across regions. Second, when respondents are associating mental images, the term "climate change" might have semantic framing effects and might be a source of bias. In general, this priming effect is not significant and does not affect conclusions according to previous studies (Lorenzoni et al., 2006). Third, terms that are not mentioned as the top three could be important concepts and some associations may be directly triggered by proximate events. For example, in August 2019 when the survey was taking place in Hangzhou, Typhoon Lekima landed in nearby east coast of China. This is a key reason for the high percentage of *disaster* image in Hangzhou. This might also explain why *disaster* has multiple subcategories, and its popularity is dramatically imbalanced across cities (Figure S3 in Supporting Information S1). An important research direction in future work is to further investigate the drivers that shape short-term dynamics of climate change perceptions and how misperceptions influence public policy support and individual behavioral changes.

5. Conclusions

China has pledged to peak its carbon emissions by 2030 and achieve carbon neutrality by 2060. To take advantage of this momentum, we need to delineate how the Chinese lay public perceive climate change to inform policy makers and promote collective actions. This study provides an updated open-ended climate change opinion survey in six Chinese cities based on face-to-face interviews and mental image elicitation tasks. We identify 10 mental images and 37 subcategories that fully enclose how climate change is conceptualized by the Chinese public. We find Chinese people largely confuse climate change with local micro-climate and air pollution. This misinterpretation is mainly due to inadequate social attention and points to the need for more extensive information campaign. Compared to Western countries, Chinese people are less skeptical about climate change, probably due to different political realities and fewer conflicting framings in Chinese media coverage. Meanwhile, climate change as a concept exhibits significant geographic and socio-demographic heterogeneity, highlighting the necessity for targeted and region-specific communication strategies across the country.

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

Data used in this research and reproducing R codes are deposited on Zenodo (https://zenodo.org/record/4687501#.YHb9QOhKhPY) (Yang, 2021).

References

Ballew, M. T., Leiserowitz, A., Roser-Renouf, C., Rosenthal, S. A., Kotcher, J. E., Marlon, J. R., et al. (2019). Climate change in the American mind: Data, tools, and trends. *Environment: Science and Policy for Sustainable Development*, *61*, 4–18. https://doi.org/10.1080/00139157.2019.1589300

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*, 110316. https://doi.org/10.18637/jss.v067.i01

Bliuc, A.-M., McGarty, C., Thomas, E. F., Lala, G., Berndsen, M., & Misajon, R. (2015). Public division about climate change rooted in conflicting socio-political identities. *Nature Climate Change*, *5*, 226–229. https://doi.org/10.1038/nclimate2507

Boudet, H., Giordono, L., Zanocco, C., Satein, H., & Whitley, H. (2020). Event attribution and partisanship shape local discussion of climate change after extreme weather. *Nature Climate Change*, *10*, 69–76. https://doi.org/10.1038/s41558-019-0641-3

Bullock, J. G. (2011). Elite influence on public opinion in an informed electorate. *American Political Science Review*, *105*, 496–515. https://doi.org/10.1017/s0003055411000165

Chapman, D. A., Corner, A., Webster, R., & Markowitz, E. M. (2016). Climate visuals: A mixed methods investigation of public perceptions of climate images in three countries. *Global Environmental Change*, *41*, 172–182. https://doi.org/10.1016/j.gloenvcha.2016.10.003

Connor, L. H., & Higginbotham, N. (2013). "Natural cycles" in lay understandings of climate change. *Global Environmental Change*, *23*(6), 1852–1861. https://doi.org/10.1016/j.gloenvcha.2013.07.002

Copsey, T., Hoijtink, L., Shi, X., & Whitehead, S. (2014). *China: How the people of China live with climate change and what communication can do*. BBC Media Action.

Dunlap, R. E., McCright, A. M., & Yarosh, J. H. (2016). The political divide on climate change: Partisan polarization widens in the U.S. environment. *Science and Policy for Sustainable Development*, *58*, 4–23. https://doi.org/10.1080/00139157.2016.1208995

Egan, P. J., & Mullin, M. (2017). Climate change: US public opinion. *Annual Review of Political Science*, *20*, 209–227. https://doi.org/10.1146/annurev-polisci-051215-022857

Farsalinos, K. E., Poulas, K., Voudris, V., & Le Houezec, J. (2017). Prevalence and correlates of current daily use of electronic cigarettes in the European Union: Analysis of the 2014 Eurobarometer survey. *Internal and Emergency Medicine*, *12*, 757–763. https://doi.org/10.1007/s11739-017-1643-7

Finucane, M. L., Slovic, P., Mertz, C. K., Flynn, J., & Satterfield, T. A. (2000). Gender, race, and perceived risk: The 'white male' effect. *Health, Risk & Society*, *2*, 159–172. https://doi.org/10.1080/713670162

Fleming, W., Hayes, A. L., Crosman, K. M., & Bostrom, A. (2021). Indiscriminate, irrelevant, and sometimes wrong: Causal misconceptions about climate change. *Risk Analysis*, *41*(1), 157–178. https://doi.org/10.1111/risa.13587

Gallagher, K. S., Zhang, F., Orvis, R., Rissman, J., & Liu, Q. (2019). Assessing the policy gaps for achieving China's climate targets in the Paris agreement. *Nature Communications*, *10*, 1256. https://doi.org/10.1038/s41467-019-09159-0

Guan, D., Meng, J., Reiner, D. M., Zhang, N., Shan, Y., Mi, Z., et al. (2018). Structural decline in China's CO_2 emissions through transitions in industry and energy systems. *Nature Geoscience*, *11*, 551–555. https://doi.org/10.1038/s41561-018-0161-1

Gustafson, A., Rosenthal, S. A., Ballew, M. T., Goldberg, M. H., Bergquist, P., Kotcher, J. E., et al. (2019). The development of partisan polarization over the Green New Deal. *Nature Climate Change*, *9*, 940–944. https://doi.org/10.1038/s41558-019-0621-7

Han, J., Sun, S., & Lu, Y. (2017). Framing climate change: A content analysis of Chinese mainstream newspapers from 2005 to 2015. *International Journal of Communication*, *11*, 2889–2911.

Higginbotham, N., Connor, L. H., & Baker, F. (2014). Subregional differences in Australian climate risk perceptions: Coastal versus agricultural areas of the Hunter Valley, NSW. *Regional Environmental Change*, *14*, 699–712. https://doi.org/10.1007/s10113-013-0529-0

Hornsey, M. J., Harris, E. A., Bain, P. G., & Fielding, K. S. (2016). Meta-analyses of the determinants and outcomes of belief in climate change. *Nature Climate Change*, *6*, 622–626. https://doi.org/10.1038/nclimate2943

Hornsey, M. J., Harris, E. A., & Fielding, K. S. (2018). Relationships among conspiratorial beliefs, conservatism and climate scepticism across nations. *Nature Climate Change*, *8*, 614–620. https://doi.org/10.1038/s41558-018-0157-2

Howe, P. D., Marlon, J. R., Mildenberger, M., & Shield, B. S. (2019). How will climate change shape climate opinion? *Environmental Research Letters*, *14*, 113001. https://doi.org/10.1088/1748-9326/ab466a

Howe, P. D., Mildenberger, M., Marlon, J. R., & Leiserowitz, A. (2015). Geographic variation in opinions on climate change at state and local scales in the USA. *Nature Climate Change*, *5*, 596–603. https://doi.org/10.1038/nclimate2583

Jamelske, E., Boulter, J., Jang, W., Barrett, J., Miller, L., & Han, W. L. (2015). Examining differences in public opinion on climate change between college students in China and the USA. *Journal of Environmental Studies and Sciences*, *5*, 87–98. https://doi.org/10.1007/s13412-015-0229-9

Jenkins-Smith, H. C., Ripberger, J. T., Silva, C. L., Carlson, D. E., Gupta, K., Carlson, N., et al. (2020). Partisan asymmetry in temporal stability of climate change beliefs. *Nature Climate Change*, *10*, 322–328. https://doi.org/10.1038/s41558-020-0719-y

Kempton, W. (1991). Lay perspectives on global climate change. *Global Environmental Change*, *1*, 183–208. https://doi.org/10.1016/0959-3780(91)90042-r

Lee, T. M., Markowitz, E. M., Howe, P. D., Ko, C.-Y., & Leiserowitz, A. A. (2015). Predictors of public climate change awareness and risk perception around the world. *Nature Climate Change*, *5*, 1014–1020. https://doi.org/10.1038/nclimate2728

Leiserowitz, A. (2006). Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Climatic Change*, *77*, 45–72. https://doi.org/10.1007/s10584-006-9059-9

Leiserowitz, A., Maibach, E., Rosenthal, S., Kotcher, J., Bergquist, P., Ballew, M., et al. (2020). *Climate change in the American mind: April 2020*. Yale Program on Climate Change Communication, Yale University and George Mason University.

Leviston, Z., Price, J., & Bishop, B. (2014). Imagining climate change: The role of implicit associations and affective psychological distancing in climate change responses. *European Journal of Social Psychology*, *44*, 441–454. https://doi.org/10.1002/ejsp.2050

Lewandowsky, S., Gignac, G. E., & Vaughan, S. (2013). The pivotal role of perceived scientific consensus in acceptance of science. *Nature Climate Change*, *3*, 399–404. https://doi.org/10.1038/nclimate1720

Liu, W., Zeng, L., & Wang, Q. (2021). Psychological distance toward air pollution and purchase intention for new energy vehicles: An investigation in China. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.569115

Lorenzoni, I., Leiserowitz, A., De Franca Doria, M., Poortinga, W., & Pidgeon, N. F. (2006). Cross-national comparisons of image associations with "global warming" and "climate change" among laypeople in the United States of America and Great Britain. *Journal of Risk Research*, *9*, 265–281. https://doi.org/10.1080/13669870600613658

Lorenzoni, I., & Pidgeon, N. F. (2006). Public views on climate change: European and USA perspectives. *Climatic Change*, *77*, 73–95. https://doi.org/10.1007/s10584-006-9072-z

Maiella, R., La Malva, P., Marchetti, D., Pomarico, E., Di Crosta, A., Palumbo, R., et al. (2020). The psychological distance and climate change: A systematic review on the mitigation and adaptation behaviors. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.568899

McCaffrey, M. S., & Buhr, S. M. (2008). Clarifying climate confusion: Addressing systemic holes, cognitive gaps, and misconceptions through climate literacy. *Physical Geography*, *29*, 512–528. https://doi.org/10.2747/0272-3646.29.6.512

Ogunbode, C. A., Demski, C., Capstick, S. B., & Sposato, R. G. (2019). Attribution matters: Revisiting the link between extreme weather experience and climate change mitigation responses. *Global Environmental Change*, *54*, 31–39. https://doi.org/10.1016/j.gloenvcha.2018.11.005

O'Neill, S. J., Boykoff, M., Niemeyer, S., & Day, S. A. (2013). On the use of imagery for climate change engagement. *Global Environmental Change*, *23*, 413–421.

O'Neill, S. J., Williams, H. T. P., Kurz, T., Wiersma, B., & Boykoff, M. (2015). Dominant frames in legacy and social media coverage of the IPCC Fifth Assessment Report. *Nature Climate Change*, *5*, 380–385.

Poortinga, W., Whitmarsh, L., Steg, L., Böhm, G., & Fisher, S. (2019). Climate change perceptions and their individual-level determinants: A cross-European analysis. *Global Environmental Change*, *55*, 25–35. https://doi.org/10.1016/j.gloenvcha.2019.01.007

Pugliese, A., & Ray, J. (2009). A heated debate: Global attitudes toward climate change. *Harvard International Review*, *31*, 64–68.

Scruggs, L., & Benegal, S. (2012). Declining public concern about climate change: Can we blame the great recession? *Global Environmental Change*, *22*, 505–515. https://doi.org/10.1016/j.gloenvcha.2012.01.002

Shi, X., Sun, L., Chen, X., & Wang, L. (2019). Farmers' perceived efficacy of adaptive behaviors to climate change in the Loess Plateau, China. *The Science of the Total Environment*, *697*, 134217. https://doi.org/10.1016/j.scitotenv.2019.134217

Shwom, R., Bidwell, D., Dan, A., & Dietz, T. (2010). Understanding U.S. public support for domestic climate change policies. *Global Environmental Change*, *20*, 472–482. https://doi.org/10.1016/j.gloenvcha.2010.02.003

Smith, N., & Leiserowitz, A. (2012). The rise of global warming skepticism: Exploring affective image associations in the United States over time. *Risk Analysis*, *32*, 1021–1032. https://doi.org/10.1111/j.1539-6924.2012.01801.x

Tvinnereim, E., & Fløttum, K. (2015). Explaining topic prevalence in answers to open-ended survey questions about climate change. *Nature Climate Change*, *5*, 744–747. https://doi.org/10.1038/nclimate2663

Tvinnereim, E., Liu, X., & Jamelske, E. M. (2017). Public perceptions of air pollution and climate change: Different manifestations, similar causes, and concerns. *Climatic Change*, *140*, 399–412. https://doi.org/10.1007/s10584-016-1871-2

Wang, B., Shen, Y., & Jin, Y. (2017). Measurement of public awareness of climate change in China: Based on a national survey with 4,025 samples. *Chinese Journal of Population Resources and Environment*, *15*, 285–291. https://doi.org/10.1080/10042857.2017.1418276

Wang, B., & Zhou, Q. (2020). Climate change in the Chinese mind: An overview of public perceptions at macro and micro levels. *WIREs Climate Change*, *11*, e639. https://doi.org/10.1002/wcc.639

Wang, H., Lu, X., Deng, Y., Sun, Y., Nielsen, C. P., Liu, Y., et al. (2019). China's CO_2 peak before 2030 implied from characteristics and growth of cities. *Nature Sustainability*, *2*, 748–754. https://doi.org/10.1038/s41893-019-0339-6

Wang, S., Corner, A., Chapman, D., & Markowitz, E. (2018). Public engagement with climate imagery in a changing digital landscape. *WIREs Climate Change*, *9*, e509. https://doi.org/10.1002/wcc.509

Weber, E. U. (2016). What shapes perceptions of climate change? New research since 2010. *WIREs Climate Change*, *7*, 125–134. https://doi.org/10.1002/wcc.377

Wei, J., Hansen, A., Zhang, Y., Li, H., Liu, Q., Sun, Y., & Bi, P. (2014). Perception, attitude and behavior in relation to climate change: A survey among CDC health professionals in Shanxi province, China. *Environmental Research*, *134*, 301–308. https://doi.org/10.1016/j.envres.2014.08.006

Winden, M., Jamelske, E., & Tvinnereim, E. (2018). A contingent valuation study comparing citizen's willingness-to-pay for climate change mitigation in China and the United States. *Environmental Economics and Policy Studies*, *20*, 451–475. https://doi.org/10.1007/s10018-017-0202-9

Xie, L. (2015). The story of two big chimneys: A frame analysis of climate change in US and Chinese newspapers. *Journal of Intercultural Communication Research*, *44*, 151–177. https://doi.org/10.1080/17475759.2015.1011593

Yang, J. (2021). *Jason1996NJU/Climate_Change_Mental_Image_China: Perceptions of Climate Change in China (v1.0)*. Zenodo. https://doi.org/10.5281/zenodo.4687501

Yang, J., Zhou, Q., Liu, X., Liu, M., Qu, S., & Bi, J. (2018). Biased perception misguided by affect: How does emotional experience lead to incorrect judgments about environmental quality? *Global Environmental Change*, *53*, 104–113. https://doi.org/10.1016/j.gloenvcha.2018.09.007

Yu, H., Wang, B., Zhang, Y.-J., Wang, S., & Wei, Y.-M. (2013). Public perception of climate change in China: Results from the questionnaire survey. *Natural Hazards*, *69*, 459–472. https://doi.org/10.1007/s11069-013-0711-1

Zhang, B., van der Linden, S., Mildenberger, M., Marlon, J. R., Howe, P. D., & Leiserowitz, A. (2018). Experimental effects of climate messages vary geographically. *Nature Climate Change*, *8*, 370–374. https://doi.org/10.1038/s41558-018-0122-0