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Adaptation, exposure, and politics: Local extreme heat and global climate change risk perceptions in the phoenix metropolitan region, USA

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ABSTRACT

Cities around the planet are facing climate change risks including (but not limited to) extreme heat, drought, wildfire, and flooding. Urbanites perceptions of the risks posed by climate change influence communities' mitigation and adaption responses, but there is limited literature on the perceptions of climate risks in cities. Urban climate change impacts are multi-scalar, but existing work isolates local versus global considerations. Adaptive capacity affects climate change impacts, yet scholarship on urban climate typically is not framed through an adaptive capacity lens. In this study, we explore how exposure to heat, place-based vs. social connections, and socio-demographics affect residents' perception that extreme heat (local extreme heat) or climate change (global climate change) seriously affects their household and way of life. Using a survey from metropolitan Phoenix, Arizona (USA), an area facing increased extreme heat and rapid climate change, this study shows that urbanites' perceptions of risks posed by extreme weather conditions and global climate change are mediated in part by the existing urban infrastructure and planning (e.g., access to urban green infrastructure) and magnified by exposure to heat, but also shaped by political ideology. We also find that place attachment and Latino or Hispanic ethnic background positively affect perceptions of local extreme heat, while high income negatively influences perceptions of global climate change impacts. Heat exposure positively, whereas green infrastructure negatively affects risk perceptions of both local extreme heat and global climate change. Risk perceptions are influenced by exposure and adaptive capacity. Identifying the drivers of risk perceptions across different local contexts is an essential step for generating in-situ climate adaptation strategies for cities.

1. Introduction

Cities are central to the generation of climate change and its impacts on humans, yet people within cities are not affected universally (Pelling, 2003; Wilhelmi & Hayden, 2010; Wolf, Adger, Lorenzoni, Abrahamson, & Raine, 2010). Extreme heat events occur more frequently and with greater intensity due to climate change with significant negative consequences, especially for socio-economically disadvantaged urban populations (Bolitho & Miller, 2017; Dong et al., 2020; Mitchell & Chakraborty, 2014; Wilhelmi & Hayden, 2010). Heat stress is becoming more prevalent in American cities, especially in the Southwest (Chow, Chuang, & Gober, 2012; Pincetl, Chester, & Eisenman, 2016); yet extreme heat has also led to death and illness in regions with different climates, such as Chicago, Portland, and Atlanta (Habeeb, Vargo, & Stone, 2015; Sarofim et al., 2016). Heat stress reduces job efficiency, raises pollutant levels, and increases cooling energy demands in buildings (Harlan & Ruddell, 2011; Lundgren, Kuklane, Gao, & Holmer, 2013). Minoritized communities are more vulnerable and disproportionately exposed to extreme summer heat, heat-related sickness, energy costs, and mortality due to urban thermal inequalities (Dialesandro, Brazil, Wheeler, & Abunnasr, 2021); people of color are exposed to 1 °C higher heat than their white counterparts (Hsu, Sheriff, Chakraborty, & Manya, 2021) in cities across the US. Climate policies and actions in local contexts become embedded in minoritized communities' climate vulnerabilities, which in turn may influence risk perceptions. Understanding differences in perception of local and global climate change risks is critical to increase adaptive capacity and redress historic injustices through climate action.

Cities grappling with climate change adaptation and mitigation policies must recognize that there is great variation in communities' and

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individuals' vulnerability. Vulnerability is multidimensional including exposure to natural hazards and changing climate, as well as the sensitivity of systems or populations to absorb impact, and people's adaptive capacity to recover from the exposure (Adger, 2006; O'Brien, Eriksen, Nygaard, & Schjolden, 2007; Turner et al., 2003). Adaptive capacity is the ability to take anticipatory and precautionary actions to address the impacts of changing climate (Adger & Vincent, 2005; Gallopín, 2006; Smit & Wandel, 2006). Adaptive capacity incorporates a nested hierarchy of vulnerability encompassing multi-level (i.e., individuals, social groups, cities) and multi-scale (parcel to the planet) vulnerability. This nested hierarchy reflects local to broader levels of exposure to risk (Smit & Wandel, 2006). Adaptive capacity depends on factors such as political and economic systems (e.g., public opinion, political will, financial capacity) and is shaped by various physical and social aspects in a given urban context (e.g., the conditions of the green infrastructure, urban planning) (Daloğlu Çetinkaya, Yazar, Kılınç, & Güven, 2022; Krellenberg et al., 2014; Nelson et al., 2010; Pelling & High, 2005; Yazar et al., 2020b). At the local scale, extreme weather results in exposure that individuals are more or less able to withstand based on their adaptive capacity (Brody, Zahran, Vedlitz, & Grover, 2008; Harlan et al., 2014; Yazar, York, & Kyriakopoulos, 2021). Utilizing an adaptive capacity framing provides an opportunity to explicitly explore multiple scales and to connect risk perception to social and physical dimensions.

While there is innovation in the development of climate change adaptation strategies and plans, more attention must be given to individuals' perceptions of climate change and its potential risks that are associated with their adaptive capacity (Chow et al., 2012; Sheridan & Allen, 2018). It is unlikely that people will support policies and demand formal actions to deal with a problem they do not think is real. Ding, Maibach, Zhao, Roser-Renouf, and Leiserowitz (2011), for instance, find that beliefs in climate change predict support for climate policies. Climate change beliefs are also affected by factors such as ethnicity and race. Yazar et al. (2021) find that non-Hispanic White individuals are less likely to believe climate change is happening in the Phoenix Metro Area than Hispanic individuals. Our study explicitly considers risk a critical element for policy support and adoption, as well as collective action, and examines both local and global risk dimensions within an urban environment. Urban scholars and practitioners need to understand the factors leading to divergent risk perceptions within cities facing substantial climate change impacts.

Despite the growing literature on vulnerability and risk assessments of urban communities to changing climate, the literature on the perceptions of risks posed by local weather conditions and climate change often is not framed through an adaptive capacity lens; nor are the multilevel and scalar aspects of vulnerability explored. Often climate risk research isolates local versus global, therefore missing opportunities to compare and contrast multi-level and scalar considerations. In this study, we unveil the factors influencing perception of the risks posed by local extreme weather and global climate change. We explore how personal exposure to extreme heat and various aspects of individual-level adaptive capacity affect locals' perception of risks: 1) extreme heat, and 2) global climate change in the fifth largest US city that is facing a rapidly changing climate: the Phoenix Metropolitan Area. We examine how people with varying heat exposure, socio-demographic attributes and political ideologies perceive extreme heat versus climate change risks. We investigate the role of local adaptive capacity—specifically green infrastructure, neighbourhood attachment, and social capital-in shaping climate risk perceptions. Metropolitan Phoenix is a prime study site given extreme heat and implications for an even hotter future. For example, the sweltering summer of 2020 resulted in 207 deaths in Maricopa County, Arizona (MCDPH, 2020). The Phoenix region faces substantial climate risk with high variability in vulnerability and adaptive capacity including access to green infrastructure (Zhang, Murray, & Turner Ii, 2017). We use the 2017 Phoenix Social Survey ($N = 496$), which is established as part of the Central Arizona Phoenix Long-term Ecological Research (CAP LTER) (Larson, York, Andrade, & Wittlinger, 2019). We explore connections between adaptive capacity and exposure with a hierarchal vulnerability framing to perception of local versus global climate risks.

In the next section, we provide the theoretical context describing relevant literature from urban studies and the larger social scientific scholarship on vulnerability to climate risks to explain how the factors we analyze are important for understanding the potential for collective action toward adaptive capacity. We develop a set of six hypotheses associated with perception of the risk of local extreme heat and global climate change to respondents' household and way of life. Then we provide background context on the Phoenix study site, survey design, variables, and models. In the results section, we present a conceptual model of factors that drive risk perceptions and highlight significant relationships. Our discussion section explores how income is linked to global risk perception while Latinx identity and place attachment are linked to local. Exposure, green infrastructure, social capital, and political ideology are significantly associated with both local and global risk perception. In sum, multi-scalar dimensions combine to influence individuals' risk perceptions, an important consideration for cities working to adapt to local climate change and mitigate climate change to reduce global harms.

2. Adaptive Capacity: local extreme weather vs. global climate risk perceptions

Adaptive capacity is influenced by hard and soft infrastructure (e.g., built land systems and systems of governance); social structure (e.g., social class, gender, race); and agency, which is contextualized as the ability to mobilize the aforementioned resources within existing structures (Lemos, Lo, Nelson, Eakin, & Bedran-Martins, 2016). Individual and collective adaptive capacities to recover from drastic hazards requires learning, developing skills, and being willing and able to take adaptive actions to minimize risks (de Murieta, Galarraga, & Olazabal, 2021; Marshall, Park, Adger, Brown, & Howden, 2012). Adaptive capacity scholarship often focuses on resources, socio-economic measures, and socio-psychological conditions (Chow et al., 2012; Li, Johnson, & Zaval, 2011; Thornton et al., 2020; Zaval, Keenan, Johnson, & Weber, 2014). Research on informal urban settlements, where dwellers' adaptive capacity is analyzed through physical and social environmental factors—specifically social capital, place attachments, and physical urban form—provides a new direction demonstrating the role of mutually constituted relationships between people, land, and objects (Leon-Moreta, Totaro, & Dixon, 2020; Waters & Adger, 2017).We leverage these emerging relational theories of people's adaptive capacity dependent on physical and social environmental factors to understand how they combine to affect perceived climate risks and, by extension, the potential for personal and collection action. Competing arguments in the literature exist regarding whether or not personal experience and vulnerability to local conditions heightens perceptions of extreme weather and global climate change risks (e.g., Brody et al., 2008 compared to Akerlof, Maibach, Fitzgerald, Cedeno, & Neuman, 2013).

Increasingly people throughout the world perceive climate change as a serious threat (Lee, Markowitz, Howe, Ko, & Leiserowitz, 2015), but there is limited research exploring local versus global risks. We argue the factors influencing perception of local versus global climate risks are not the same. Since unequal access to mediating infrastructure, such as green infrastructure, reproduces vulnerability and differences in risks perceptions through time, understanding the scalar dimensions of beliefs, local versus global, about the aforementioned risks can bring into focus the ways in which inequalities are created and maintained by the existing urban planning, social, and political processes. Herein, we examine the extent to which local versus global perceptions of climate risks are related to heat exposure, socio-demographics, social capital, green infrastructure, place attachment, and political ideology that can help lessen climate risks.

2.1. Exposure

Personal *exposure* to climate change-related events influences beliefs more than information about climate change in distant locations (Rudman, McLean, & Bunzl, 2013; Ruiz, Faria, & Neumann, 2020; Whitmarsh, 2009), but also the relationship between exposure to climate-related extreme weather events and global climate change beliefs erodes overtime (Egan & Mullin, 2012; Howe & Leiserowitz, 2013). The magnitude of the event also matters; individuals experiencing climate change-related weather events with less damage are less likely to believe that climate change is occurring (Yazar et al., 2021) and also discount the seriousness of climate change (Shwom et al., 2010).

H1. : Personal experience with extreme heat symptoms is associated with the perception of local extreme heat and global climate risks.

2.2. Adaptive capacity: social structure, social capital, green infrastructure

Social structure is a critical aspect of adaptive capacity. Case studies demonstrate that the failure to mitigate the social and economic impacts of climate change will result in profoundly unequal results (Keenan, Hill, & Gumber, 2018). These disparities are most often seen along with racial and ethnic divisions (Hughes & Hoffmann, 2020; Shao, Xian, Keim, Goidel, & Lin, 2017; Shwom, Bidwell, Dan, & Dietz, 2010), as well as different age and gender groups (Ballew et al., 2019; Shao et al., 2017; Shwom et al., 2010). The production and re-production of urban space echoes local politics and power asymmetries. Consequently, better infrastructure and municipal services are distributed unevenly in favor of wealthy communities (Fainstein, 2018; Soja, 2013) while simultaneously increasing the vulnerability of disadvantaged communities (Broto & Bulkeley, 2013; Fainstein, 2018). Prior work has demonstrated that socio-demographic characteristics are associated with climate change beliefs, including age (Bohr, 2017; McCright & Dunlap, 2011), race (McCright & Dunlap, 2011; Yazar et al., 2021), gender (Brody et al., 2008; Davidson & Haan, 2012; Malka, Krosnick, & Langer, 2009), income (Bohr, 2014; McCright & Dunlap, 2011), and employment (Albright & Crow, 2019; McCright & Dunlap, 2011). Here, we hypothesise that:

H2. : Socio-demographic characteristics have both positive and negative influence affecting perception of risks of local extreme heat and global climate change. In particular, we expect that racial/ethnic minorities and residents with relatively low income and education levels will perceive local extreme heat more threatening than global risks.

Researchers contextualize *social capital* as the strength of networks of trusts, reciprocity, and norms between individuals who share social identity (Dressel, Johansson, Ericsson, & Sandström, 2020; Pelling & High, 2005). Higher social capital is found to determine a higher adaptive capacity of individuals after an extreme weather event (Aldrich, 2012; Aldrich & Meyer, 2014), as well as more likely to show support for climate policy (Hao et al., 2020; Yazar & York, 2022). Studies also find that there is an imbalance in the availability of social capital among low-income residents of a community (McCarthy, 2014). For instance, in relation to the effects of a Chicago heatwave, social-capital weakness and associated barriers to accessing assistance were a pervasive reason for mortality among socio-economically disadvantaged groups (Klinenberg, 1999; Semenza et al., 1996). From this standpoint we hypothesise that:

H3. : Individuals who live in close-knit neighbourhoods will less likely acknowledge that both the risks posed by extreme heat and by global climate change are extremely or very serious for their households' and ways of life.

Green infrastructures, especially trees, mitigate the impacts of extreme heat and climate change, while unequal access is inextricably linked to wealth, race, and ethnicity (Hsu et al., 2021). Urban trees and parks increase the resilience of communities to extreme weather events such as floods (Gill, Handley, Ennos, & Pauleit, 2007; Güneralp, Güneralp, & Liu, 2015) and also increases people's adaptive capacity to cope with changing climate and extreme local weather conditions (Byrne, Lo, & Jianjun, 2015; Carter, 2018). But local policymakers and developers often focus on this green infrastructure to boost property values with little attention paid to vulnerable urban populations' needs (Pearsall, 2010; Dooling, 2009). Spatially varied local climate adaptation strategies contribute to the uneven distribution of green infrastructures, reproducing racialized patterns of environmental benefits and burdens (Brand & Baxter, 2020; Yazar et al., 2020a), especially as the location and distribution of trees and parks are affected by legacies of redlining in race-based housing and urban planning (Locke et al., 2021; Schell et al., 2020). The unequal distribution of and limited access to green infrastructure in minoritized neighbourhoods consequently increases vulnerability and affects locals' adaptive capacity during and after extreme weather events. However, research has not adequately demonstrated the extent to which green infrastructure (i.e., trees) affects people's perceptions of local weather and global climate risks. Building on existing literature that highlights a positive correlation between access to the urban green infrastructure and higher adaptive capacity to cope with extreme weather events, we hypothesise that:

H4. : Individuals who are strongly satisfied with the amount of trees in and around their neighbourhood will be less likely to perceive that the risks posed by both extreme heat and by global climate change are extremely or very serious for their households and ways of life.

2.3. The effects of place attachment

People's *place attachment* has been found to be an important indicator for their environmental behaviours and their engagement in conservation-related actions (Gosling & Williams, 2010; McCunn & Gifford, 2014). For instance, Devine-Wright, Price, and Leviston (2015) find that individuals with high levels of global attachment are more concerned about climate change comparing to individuals with stronger national attachment. Experience of extreme weather events triggered by changing climate, such as flooding, make people less certain about their future and also trigger people to leave their properties to prevent further damages, regardless of their attachment to their homes; yet people with a higher sense of place, especially those who have strong social bonding with their local communities, prefer to move back (Chamlee-Wright & Storr, 2009). Broadly, however, the relationship between place attachment and the perception of climate-related threats is unclear and suggests that experience with the extreme local weather events might increase beliefs that they cause serious risks to people's wellbeing. Here, we hypothesise that:

H5. : Individuals who are very attached to their neighbourhood will be more likely to acknowledge risks posed by local extreme heat than global climate change risks.

2.4. Political ideology

A relationship between climate change beliefs and *political ideology* in the U.S. is well established. Studies find that individuals who identify themselves as liberals are more likely to believe that climate change is happening (Bohr, 2017; Hamilton, Hartter, Lemcke-Stampone, et al., 2015; Marquart-Pyatt, McCright, Dietz, & Dunlap, 2014; Yazar et al., 2020a, 2020b). Similarly, political ideology is found one of the strongest predictors in perceiving health risks associated with extreme heat (Cutler, Marlon, Howe, & Leiserowitz, 2018).

H6. *:* Liberal political ideology is associated with perception of local extreme heat and global climate change risk.

3. The data and methods

3.1. Study area

The Phoenix Metro Area has one of the most extreme climates in the USA and the world with heat with temperatures in excess of 35.9 °C (NOAA National Centers for Environmental information, 2020), affecting an urban population of 4.8 million (ACS (American Community Survey), 2018). Phoenix's historic and current socio-spatial inequalities of risks are due in part to historical legacy of race-based segregation and redlining in urban planning (Bolin, Barreto, Hegmon, Meierotto, & York, 2013; York & Boone, 2018). Combining survey data with meteorological, and remote sensing data measuring temperatures and land use/cover configurations, Harlan, Brazel, Prashad, Stefanov, and Larsen (2006) demonstrated that neighbourhoods with lower socioeconomic status and more ethnic minorities were likely to be warmer due to lower vegetation density, a lack of local greenspace, and higher settlement density. Jenerette et al. (2007), for instance, found that high-income neighbourhoods in the Phoenix metro area are located closer to the desert with lower population density, and consequently, dwellers of these neighbourhoods are less likely affected by the extreme heat due to more vegetation to providing shade. These areas also exhibit minimal night-time temperatures that cool surface quicker than neighbourhoods in the urban core (Connors, Galletti, & Chow, 2013). Meanwhile, low-income communities are more likely to be exposed to higher air and surface temperatures due to fewer material and social resources that may help adapt to the impacts of extreme heat, such as centralized air conditioning (Harlan et al., 2006; Jenerette, Harlan, Stefanov, & Martin, 2011). Moreover, the effect of daytime surface temperature on frequency of heat illness is greater for people with lower access to air conditioning in their homes (Jenerette et al., 2016).

3.2. Data

We use the 2017 Phoenix Area Social Survey (PASS-2017) dataset (Larson et al., 2019) to test our six hypotheses. Selected variables from this dataset were analyzed using individual-level logistic regression models. The PASS-2017 dataset contains records from a total of 496 respondents, drawn from the population of residents in the Phoenix area using a random-probability sampling design. The survey was conducted in a total of 12 different neighbourhoods within the Phoenix Metro and selecting localities with diverse income levels, ethnic profiles and time of development. The survey was delivered by mail only to approximately 1400 addresses – a subset of sample addresses, approximately 13%, were drawn from prior respondents in the 2011 Phoenix Area Social Survey and the remainder were randomly selected from mailing lists for each neighbourhood. The survey was deployed from June to early August 2017. The 2017 PASS survey was mailed in a wave data collection design in the months of May through September. The first wave included the survey, a postage-paid card to request a Spanish copy of the survey (which was translated and back-translated following the requirements of ASU's Institutional Review Board), and a return envelope. This was followed by three additional mailings. The second mailing involved a reminder postcard sent to all sampled households. The third and fourth waves included the full packet sent to addresses that had not previously returned the survey. The overall response rate for the 1400 sampled households was 39.4%, yielding a sample of 496. At the neighbourhood level, the response rates varied from a low of 22.2% in one of the lowest income areas to a high of 55.6% for a middle-income agricultural fringe area (Larson et al., 2019).

3.2.1. Dependent variables

Survey respondents were asked about how serious the risks posed by *"extreme heat"* and *"global climate change"* were for their households and ways of life using a five-point scale containing ordinal categories; not at all serious, not too serious, somewhat serious, very serious and extremely serious. To compare their risk perceptions to the two scalar risks, we identified two dependent variables, namely *"the risks posed by extreme heat are extremely or very serious for my household and way of life"*, and *"the risks posed by global climate change are extremely and very serious for my household and way of life."*

Both responses to the two dependent variables are coded into a dichotomous variable, distinguishing between respondents who extremely or very seriously agreed that extreme heat and global climate change risk their households and ways of life (coded as 1) and respondents who find the two risks somewhat serious, not too serious, and not at all serious (coded as 0). Specified in this binary form, the two dependent variables focus on the respondents' attitudes at the extreme end of agreements to the risks versus attitudes ranging from moderate to strong disagreements.

Both responses to the two dependent variables are coded into a dichotomous variable, distinguishing between respondents who extremely or very seriously agreed that extreme heat and global climate change risk their households and ways of life (coded as 1) and respondents who find the two risks somewhat serious, not too serious, and not at all serious (coded as 0). Specified in this binary form, the two dependent variables focus on the respondents' attitudes at the extreme end of agreements to the risks versus attitudes ranging from moderate to strong disagreements.

3.2.2. Exposure

To explore the relationship between the two dependent variables and PASS-2017 respondents' experience of heat-related illness, we used the following question: *"During last summer, did you or anyone else in your household have symptoms related to heat or high temperatures such as leg cramps, dry mouth, dizziness, fatigue, fainting, rapid heartbeat or hallucinations?"*. The question was framed with *yes* or *no* responses. Respondents who answered "yes" are treated as the reference category against which their counterparts were compared with regard to the dependent variables of the study.

3.2.3. Adaptative capacity: social structure

For our study, we grouped three *ethnic/racial* categories, Latinx, White-Anglo, Non-Latinx Historically Excluded Groups (including African-American, Asian or Asian-American; American Indian or Native American; or any other racial background). White-Anglo is treated as the reference category against which respondents in Latinx and Non-Latinx Historically Excluded Groups are compared with regard to the dependent variables of the study.

We grouped *income* levels into three categories, namely $40 k or under, $40,001 to $80 k, and $80,001 or more. According to American Community Survey, the median income in the Phoenix Metro Area is approximately $67,800 (ACS (American Community Survey), 2018), which led to our cut off of $80 k for high income. $80,001 or more is treated as the reference category against the remaining two categories to capture differences between lower income levels.

Education levels were grouped into two broader categories distinguishing between respondents who had reported having completed any of grades 1 to 8, grades 9 to 11, high school, community college, and vocational or technical school versus respondents who reported having completed college or graduate and professional schools. The former category is treated as the reference category against which respondents in the latter category are compared with regard to the dependent variable of the study.

Beyond the socio-demographic variables embodied in our hypotheses, we controlled for other personal attributes, including gender, age, and employment status. Respondent *gender* distinguishes between respondents who identify as male versus female, and female is treated as the reference category. Respondent *age* were banded into three categories or roughly similar frequencies; i.e. 40 or younger, 41 to 56 years of age, and 57 or older. The youngest age group (i.e. 40 or younger) were treated as the reference category against which respondents in other age groups were compared with regard to the dependent variable of the study. Respondents' *employment status* grouped into two overarching categories distinguishing between respondents with full-time work versus other than full-time work. The latter category is treated as the reference category against which respondents in the former are compared with regard to the dependent variable of the study. Beyond the socio-demographics variables embodied in our hypotheses, we controlled for other personal attributes indicated below.

3.2.4. Adaptative capacity: social capital

Social capital is measured as a dichotomous variable; respondents indicating that "strongly agree" that "I live in a close-knit neighbourhood" versus other responses with "strongly agree" as the reference category.

3.2.5. Adaptative capacity: green infrastructure

Respondents' satisfaction with the amount of trees in and around their neighbourhood are grouped into two overarching categories distinguishing between respondents who are strongly satisfied as opposed to other than strongly satisfied including strongly dissatisfied, somewhat dissatisfied, neither dissatisfied nor satisfied, and somewhat satisfied. The first category is treated as the reference category with regard to the dependent variables of this study.

3.2.6. Place attachment

Place attachment is also measured as dichotomous variable; respondents indicating "strongly agree" that "I am very attached to my neighbourhood" versus other responses with "strongly agree" as the reference category.

3.2.7. Political ideology

Respondent political ideology were grouped into two overarching categories distinguishing between respondents who had self-reported being very liberal, liberal and slightly liberal as opposed to respondents who had self-reported being very conservative, conservative, slightly conservative, and moderate. The first category is treated as the reference category against which respondents in the latter category are compared with regard to the dependent variables of the study (See Table 1. for distribution properties of variables indicated above for this study).

3.3. Approach to the analysis

A total of four models are fitted using the aforementioned variables from the survey dataset. More specifically two models are created for each of the two dependent variables namely, "*the risks posed by extreme heat are extremely and very serious for my household and way of life*", and "*the risks posed by global climate change are extremely and very serious for my household and way of life.*" The models investigated the relationship between two binary dependent variables and a series of independent and control variables. We used Cramer's metric in order to show the strength of association in the models (see Annex I).

At the first stages of our analysis, we explored whether two-level logistic regression models with a random intercept at city-level would be more appropriate for this study compared to individual-level logistic regressions without city-level random effects. Given the small sample size available to this study, significant city-level effects were not detected, and therefore, the individual-level logistic regression was deemed as the preferred modelling option. Goodness-of-fit for the reported models was evaluated using the Akaike Information Criterion (AIC) metric. All analyses were carried out using R version 3.6.2 (Team & R. C, 2013).

4. Results

Two sets of models were run for perceived impacts on residents'

Table 1
Distribution properties of PASS-2017 variables considered by this study.

Variable	Distribution description	Count of respondents	Proportion of respondents against complete sample size (496 respondents)
Target variables (local vs. global phenomena)			
Respondent's extent of acknowledgment with the *risks posed by extreme heat for their households and ways of lives*	Extremely and very serious	279	56%
	Other than extremely and very serious (not at all serious, not too serious, somewhat serious)	212	43%
Respondent's extent of acknowledgment with the *risks posed by global climate change for their households and ways of lives*	Extremely and very serious	235	47%
	Other than extremely and very serious (not at all serious, not too serious, somewhat serious)	255	51%
Exposure			
Respondent symptoms related to heat or high temperatures	Yes	118	24%
	No	369	74%
Adaptive capacity: social structure			
Respondent ethnic/racial background	White-Anglo	314	63%
	Latino-Hispanic	104	21%
	Non-Latinx Historically Excluded Groups (including African American, Asian or Asian-American, Native American)	79	16%
Respondent income	$40,000 or under	101	20%
	$40,001 to $80,000	131	26%
	$80,001 or more	225	45%
Respondent highest level of school completed	College, bachelor's degree, graduate, professional school	276	57%
	Grades 1–11, high school, community, vocational, technical	208	42%
Respondent gender	Female	293	59%
	Male	195	39%
Respondent age	40 years of age or younger	157	32%
	41–56 years of age	131	26%
	57 years of age or older	200	40%
Respondent employment status	In full-time work	249	50%
	Other than full-time work (part-time work, full-time student, homemaker, retired, unemployed, or any other employment status not specifically stated)	244	49%
Adaptive capacity: social capital			

(*continued on next page*)

Table 1 (*continued*)

Variable	Distribution description	Count of respondents	Proportion of respondents against complete sample size (496 respondents)
Respondent lives in a close-knit neighbourhood	Strongly agree	62	13%
	Other than strongly agree (somewhat agree, neither disagree nor agree, somewhat disagree)	432	87%
Adaptive capacity: green infrastructure			
Respondent satisfied with the amount of trees in and around their neighbourhood	Strongly satisfied	116	23%
	Other than strongly satisfied (somewhat satisfied, neither dissatisfied nor satisfied, somewhat dissatisfied)	379	76%
Place attachment			
Respondent is very attached to their neighbourhood	Strongly agree	140	28%
	Other than strongly agree (somewhat agree, neither disagree nor agree, somewhat disagree)	352	71%
Political ideology			
Respondent political ideology	Liberal	165	33%
	Moderate or conservative	315	64%

household and way of life: one for extreme local heat risk (Model A) and a second for global-scale climate change risk (Model B). For each dependent variable, two models were run: one with socio-demographics and a second with all explanatory and control variables, including exposure, social capital, green infrastructure, place attachment, and political ideology (see Table 2 for statistical results and Fig. 1 for illustrations of the results).

4.1. Exposure

The study finds respondents self-reporting personal experience of heat-related symptoms or illness have a greater propensity to report that the risks described by both local extreme heat and global climate change are extremely or very serious (Models 2A and 2B). Thus, *H1* is confirmed.

4.2. Adaptive capacity: social structure, social capital, green infrastructure

4.2.1. Social structure

Statistically significant relationships emerged between perceived risks posed by extreme heat and *race and ethnicity,* whereas *income* is only significantly associated with perceived risks posed by global climate change, but not with local extreme heat. Other than the two aforementioned variables, we did not observe statistically significant effects for the remainder of socio-demographic characteristics analyzed. More specifically, Models 1A and 2A suggest that survey respondents from Latino or Hispanic racial backgrounds appear more likely to report that the risks described by local extreme heat are extremely or very serious compared to their counterparts from White-Anglo racial backgrounds. Models 1B and 2B, suggest that survey respondents with lower-income ($40 k or under) are more likely to report that global climate change risks are extremely or very serious compared to their counterparts with higher-income levels. Our *H2* is partially confirmed for race and ethnicity at the local scale; whereas low income shows significance at the global scale.

4.2.2. Social capital

Models 2A and 2B indicates that survey respondents who strongly agree that they live in close-knit neighbourhoods have a statistically significant lower propensity to report that the risks described by local extreme heat and global climate risks are extremely or very serious compared to their counterparts who are other than strongly agree. Effectively, individuals who strongly agree that they live in a close-knit neighbourhood are less likely to believe that the risks posed both by extreme heat and by global climate change are extremely and very serious for their households and ways of life. *H3* is confirmed for the two risks explored in this study.

4.2.3. Green infrastructure

Models 2A and 2B systematically suggest that survey respondents who are strongly satisfied with the amount of trees in and around their neighbourhood have a statistically significant lower propensity to report that the risks described by local weather and global climate risks are extremely or very serious compared to their counterparts who are other than strongly satisfied. In other words, individuals who are strongly satisfied with trees in and around their neighbourhood are less likely to perceive the risks posed by extreme heat and by climate change are extremely and very serious for their households and ways of life. Hence, our *H4* is confirmed.

4.3. Effects of place attachment

Model 2A suggests that individuals who strongly agree that they are attached to their neighbourhood have a statistically significant higher propensity to report that the risks from extreme heat are extremely or very serious compared to their counterparts who are other than strongly agree. We did not observe a similar association between place attachment and the global phenomena with regard to global climate change in Model 2B. Thus, *H5* is confirmed.

4.4. Political ideology

The study also observes that respondents who describe themselves as liberal have a greater propensity to report that the risks described by both local and global phenomena are extremely or very serious than their counterparts who position themselves as conservative to moderate (Models 2A and 2B). Hence, *H6* is confirmed.

5. Discussion

Cities are a critical nexus of climate change as contributors to climate change and a locus of exposure and adaptation. Climate change manifests itself at multiple scales with varied impacts on different communities within metropolitan areas. Risk perceptions are associated with salience and willingness to act to address climate change; thus, it is essential to understand how individuals perceive risks. This study explored how diverse factors affect perceptions of the risks posed by local extreme heat and global climate change for residents' households and ways of life.

5.1.1. Exposure

Regarding heat *exposure*, we confirmed that personal experience of

Table 2
Individual-level logistic regression models acknowledging "the risk posed by **extreme heat is extremely or very serious** for my household and my way of life (A) " [vs. somewhat serious, not too serious, or not at all serious], and "the risk posed by **global climate change is extremely or very serious** for my household and my way of life (B)" [vs. somewhat serious, not too serious, or not at all serious].

Variable	Category [vs. reference category, if predictor is categorical]	Local extreme heat risk (a) global climate change risk (B)			
		Model 1A	Model 2A	Model 1B	Model 2B
Intercept	–	−0.343 (0.404)	−0.282 (0.415)	−1.161*** (0.413)	−1.082*** (0.422)
Respondent racial background	Latino or Hispanic [vs. White-Anglo]	0.581* (0.302)	0.592* (0.309)	0.356 (0.296)	0.408 (0.301)
	Non-Latino Historically Excluded Groups (including African-American, Asian or Asian-American, Native American) [vs. White-Anglo]	0.050 (0.311)	0.073 (0.321)	−0.272 (0.325)	−0.311 (0.329)
Respondent income	$40,000 or under [vs. $80,001 or more]	0.169 (0.307)	0.211 (0.314)	0.547* (0.312)	0.531* (0.316)
	$40,001 to $80,000 [vs.$80,001 or more]	0.143 (0.254)	0.125 (0.259)	0.174 (0.257)	0.149 (0.263)
Respondent highest level of school completed	College, graduate / professional school [vs. grades 1 to 11, high school, community college, vocational / technical school]	−0.284 (0.236)	−0.289 (0.243)	−0.176 (0.240)	−0.149 (0.244)
Respondent gender	Female [vs. male]	0.104 (0.219)	0.158 (0.226)	0.071 (0.223)	0.102 (0.228)
Respondent age	41 to 56 years of age [vs. 40 or younger]	0.217 (0.284)	0.153 (0.289)	0.466 (0.288)	0.477 (0.293)
	57 or older [vs. 40 or younger]	−0.278 (0.277)	−0.331 (0.291)	0.331 (0.283)	0.413 (0.294)
Respondent employment status	In full-time employment [vs. any other employment status]	−0.023 (0.233)	−0.058 (0.238)	−0.076 (0.235)	−0.084 (0.239)
Respondent symptoms related to heat or high temperatures	Yes [vs. no]		0.749*** (0.264)		0.723*** (0.259)
Respondent lives in a close-knit neighbourhood	Strongly agree [vs. somewhat agree, neither disagree nor agree, somewhat disagree]		−0.796** (0.362)		−0.806** (0.368)
Respondent satisfied with the amount of trees in the neighbourhood	Strongly satisfied [vs. somewhat satisfied, neither dissatisfied nor satisfied, somewhat dissatisfied]		−0.663** (0.264)		−0.577** (0.273)
Respondent is very attached to their neighbourhood	Strongly agree [vs. somewhat agree, neither disagree nor agree, somewhat disagree]		0.563*** (0.288)		0.383 (0.282)
Respondent political ideology	Liberal [vs. moderate or conservative]		1.245*** (0.239)		1.713*** (0.243)
Model metrics					
Sample size		433	430	432	429
Akaike information criterion		563.3	550.7	551.4	544.5

Statistical significance identifiers: {≤0.001: '***'}; {0.05: '**'}; {0.10: '*'}.

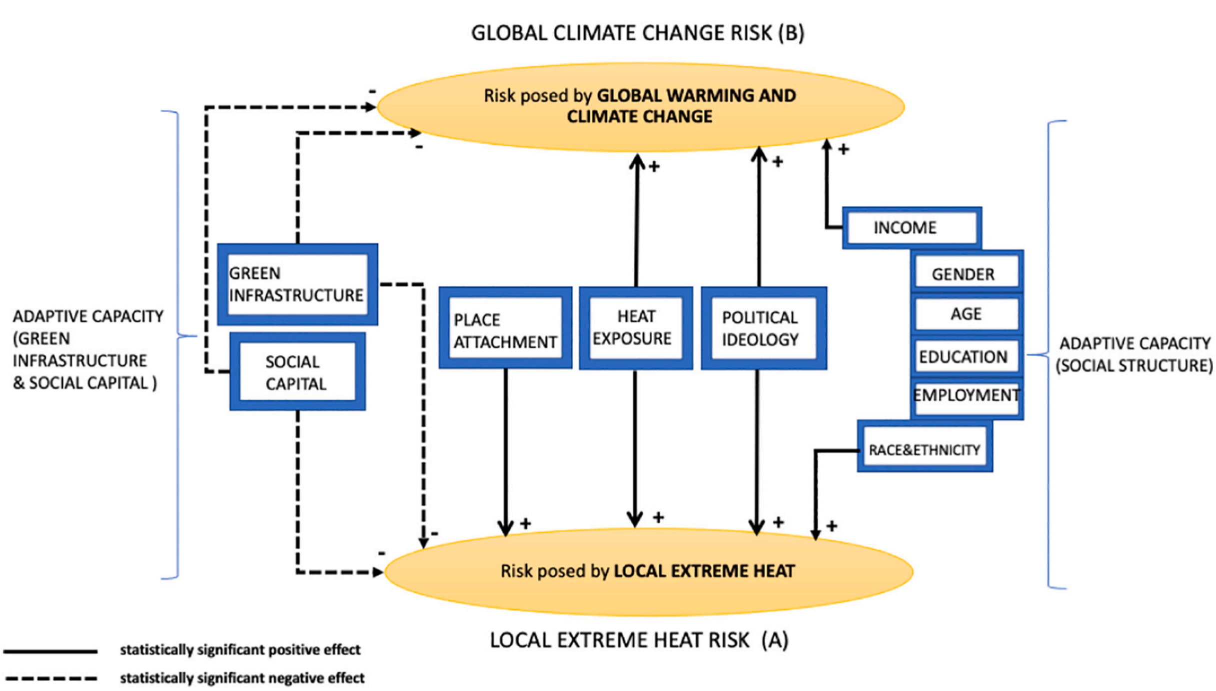

Fig. 1. Factors drive perceptions of local extreme heat and global climate change risks.

heat-related symptoms or illness is associated to a greater propensity of acknowledging the severity of risks related to extreme heat and global climate change. The literature shows that the degree of seriousness in personal damage and time duration after the damage affect people's perceptions about the seriousness of climate change (Egan & Mullin, 2012). Although not surprising, this finding underscores the potential for complacency among people who do not personally experience exposure and perceive local weather conditions or global climate change to be a threat to their households and ways of life.

5.1.2. Adaptive capacity: social structure, social capital, green infrastructure

Social structure affects risk perception; *race and ethnicity* are associated with the perceived risks posed by extreme heat, whereas *income* is associated with the perceived risks posed by global climate change. More specifically, individuals with Latino or Hispanic racial background are more likely to perceive the risks caused by extreme heat compared to White-Anglo and other historically excluded groups. Respondents with the lowest-income levels ($40 k or under), are more likely to perceive the risks posed by global climate change compared to their counterparts with higher-income. These findings align with the literature that links racial or ethnic status and income level to the adaptive capacity to respond to hazards (Chow et al., 2012; Harlan et al., 2006). Our results suggest important differences between ethnicity and race, as well as income, for local versus global risks perceptions. Specifically, Hispanic and Latinx residents in metropolitan Phoenix are on the front lines of the local extreme weather conditions. This may be attributed to the power imbalances of historic redlining and financing (Bolin et al., 2013) that both fuelled the lack of investment in green infrastructure in minority neighbourhoods and constrained minoritized communities' ability to move out of heat stressed areas of the city. Income is more closely aligned with perception of global risks, which may be related to affordability of individual mitigation efforts, such as access and electricity costs for air conditioning, or employment in high exposure jobs, such as outdoor work. Further examining the reasons underlying these patterns is an area for future research.

Collective action is needed to deal with climate change. Still, despite the observed impacts of climate change, climate scepticism manifests itself among particular social groups in the US: men, White people, political conservatives, and older Americans are more likely to be sceptical than their counterparts (Leiserowitz, Roser-Renouf, Marlon, & Maibach, 2021). From a *social capital* perspective, we find that respondents who live in close-knit neighbourhoods are less likely to acknowledge the risks posed by both extreme heat and by global climate change. This result fits within the literature suggesting that higher social capital increases adaptive capacity (Aldrich, 2012; Aldrich & Meyer, 2014), thereby reducing potential impact of risk. It may also be a worrisome indicator if we expect communities and neighbourhoods to come together to collectively tackle extreme heat and climate change, since those in the best position to do so based on their social capital may be less likely to act based on the risks they perceive.

In terms of *green infrastructure*, our analysis finds that individuals who are strongly satisfied with the amount of trees in and around their neighbourhood are less likely to acknowledge risks posed by extreme heat and global climate change. The shading and cooling benefits of trees likely limits their exposure to heat and associated perceived risks, but also may indicate the ties between green infrastructure and racial and economic injustice. Studies find that less affluent residents in the Phoenix area live in areas with less greenspace and have socio-spatial disadvantages in accessing green infrastructure (Harlan et al., 2006; Jenerette et al., 2007; Jenerette et al., 2011), but this is not unique to Phoenix since minoritized communities typically have lower tree canopy throughout the USA (Hsu et al., 2021).

5.1.3. Place attachment

The role of *place attachment* suggests different patterns in acknowledging the severity of risks posed by extreme heat or global climate change. More specifically, individuals who are very attached to their neighbourhood perceive the risk posed by extreme heat as extremely or very serious for their households and ways of life. Yet, local place attachment is not significantly associated with perceived risks from global climate change. While evidence suggests that individuals with high levels of global attachment are more concerned about climate change compared to individuals with stronger national attachment (Devine-Wright et al., 2015), our results show that local neighbourhood (sub-national) attachment connects with local weather conditions but does not necessarily to global climate change. Give that place attachment has multi-scalar dimensions that may related differently to various environment risks, this is an avenue for future research.

5.1.4. Political ideology

From a *political ideology* perspective, we find that individuals who describe themselves as liberal have a greater propensity to acknowledge the risks posed by extreme heat and by global climate change. This supports existing findings suggesting that people with liberal political beliefs are more likely to recognize the risks posed by climate change and support policies to tackle extreme weather changes compared to people who are moderate and conservative (Bohr, 2017; Hamilton et al., 2015; Marquart-Pyatt et al., 2014; McCright & Dunlap, 2011).

Overall, local extreme weather and global climate risk perceptions are greatly affected by social structure (race, ethnicity, and income), and local adaptive capacity (green infrastructure, social capital, and place attachment). There are important scalar dimensions to perceptions of local versus global risk; for instance, social structure, specifically income, is associated with global climate risk perception; whereas Latinx identity is associated with the perception of local risk. Interestingly high levels of social capital and satisfaction with tree canopy reduce the perception of both local and global risks, perhaps illustrating a buffering effect of adaptive capacity at the neighbourhood level. While local place attachment is only associated with local climate risk perception. Exposure and political ideology are strong and significant predictors of both local and global risk illustrating critical links that span scale.

6. Conclusion

Analysing the drivers affecting people's perceptions of global and local climate risks is essential to understand people's existing vulnerabilities and adaptive capacities in the midst of changing climate and weather patterns. This study investigated the Phoenix metro area urban population's perceptions of two risks, extreme heat and global climate change, as explained by satisfaction with the amount of trees in and around their neighbourhood, their attachment to their neighbourhood, their sense of close-knit relations in their neighbourhoods. Social structural factors influence vulnerability and adaptive capacity. Personal exposure to heat and political beliefs shape perception of climate risks. Global versus local risks are influenced by different factors illustrating the multi-scalar dimensions of climate risks in cities.

As socio-spatial and socio-demographic inequalities vary in each city, these inequalities must be taken into account when deploying climate adaptation actions. Successful and just urban climate adaptation policies and actions are urgently required to alleviate rising heat stress, yet the most powerful are less likely to perceive these risks or personally experience the impacts of climate change and extreme heat. Thus, there is danger in the reproduction of injustice through time and across racialized space that is reinforced by the differences in perceived risks. Importantly, our results indicate that historic inequities are exacerbated by differential perceptions across social groups, especially through increased exposure and levels of lower satisfaction with green infrastructure. In this sense, it is important to unveil the ways local or state governments act, or fail to act, on behalf of urban residents, especially low-income households and minoritized communities, facing climate change impacts. The scalar dimensions of beliefs about the aforementioned risks, therefore, can bring into particularly sharp focus the ways in which inequalities are created and maintained by the existing urban planning, social and political processes. Consequently, adaptive capacities of urban populations cannot be understood without the scales of institutions and organizations embedded within the existing socio-political, economic and infrastructure contexts. Considering the increasingly urbanized planet, more research is needed to understand how the existing infrastructure, planning, and political conditions affect people's risk perceptions in other urban contexts. We argue that our results also provide important insights for researchers to consider multiple aspects of adaptive capacity better to understand risk perceptions with a given physical urban condition.

This paper has demonstrated that the ever-increasing vulnerability of cities to local and global climate change are perceived differently depending on urban residents' adaptive capacity based on ethnicity/race, income, their proximity to urban green space, their place attachment and social capital, personal experiences of heat-related symptoms or illnesses, and political beliefs. Identifying the drivers of risk perceptions in different local contexts are an essential step for generating in-situ climate adaptation strategies. More importantly, after identifying factors that trigger risk perceptions, more studies are needed to alleviate the rigid climate strategies that exacerbate the legacy of inequality and negligence of poverty in cities similar to the Phoenix Metro Area.

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CRediT authorship contribution statement

Mahir Yazar: Conceptualization, Methodology, Writing-Original draft preparation, Writing-Reviewing, Software. **Abigail York***:* Supervision, Methodology, Writing-Reviewing. **Kelli L. Larson**: Methodology, Reviewing and Editing**.**

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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