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Increasing ambient temperature reduces emotional well-being

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ABSTRACT

This study examines the impact of ambient temperature on emotional well-being in the U.S. population aged 18+. The U.S. is an interesting test case because of its resources, technology and variation in climate across different areas, which also allows us to examine whether adaptation to different climates could weaken or even eliminate the impact of heat on well-being. Using survey responses from 1.9 million Americans over the period from 2008 to 2013, we estimate the effect of temperature on well-being from exogenous day-to-day temperature variation within respondents' area of residence and test whether this effect varies across areas with different climates. We find that increasing temperatures significantly reduce well-being. Compared to average daily temperatures in the 50–60 °F (10–16 °C) range, temperatures above 70 °F (21 °C) reduce positive emotions (e.g. joy, happiness), increase negative emotions (e.g. stress, anger), and increase fatigue (feeling tired, low energy). These effects are particularly strong among less educated and older Americans. However, there is no consistent evidence that heat effects on well-being differ across areas with mild and hot summers, suggesting limited variation in heat adaptation.

1. Introduction

While the empirical link between heat exposure and mortality rates is well-established (Curriero et al., 2002; Deschênes and Greenstone, 2011; Gasparrini et al., 2015; Kovats and Hajat, 2008), little is known about the effect of heat exposure on mental health. Previous studies have focused on suicide mortality and indicate that heat exposure is associated with increased suicide rates (Basagaña et al., 2011; Kim et al., 2016; Maes et al., 1994; Page et al., 2007; Qi et al., 2015). One study has found an impact of heat exposure on hospital admissions for mental and behavioral disorders (Hansen et al., 2008). Related research in psychology and economics has suggested that heat exposure reduces emotional wellbeing (Keller et al., 2005), increases interpersonal aggression (Anderson and Anderson, 1998; Anderson and Bushman, 2002) and diminishes life satisfaction (Connolly, 2013; Denissen et al., 2008; Lucas and Lawless, 2013; Schwarz and Clore, 1983). Together, these findings indicate that heat exposure may adversely impact mental health and that global climate change, by increasing exposure to extreme heat, could similarly have negative consequences for mental health (Berry et al., 2010).

In this study, we use survey data on 1.9 million Americans to examine the impact of ambient temperatures on emotional well-being. Our main goal is to test for evidence of a psychological link between heat exposure and emotional well-being, which could contribute to the impact of heat on mental health. Furthermore, while previous research focused on hospital admissions and suicide mortality, we obtain an estimate of the sub-clinical impact of ambient temperatures on individual's emotional well-being and quality of life in the U.S. population. Finally, we explore empirically whether adaptation to hotter climates could potentially mitigate the effect of heat exposure on emotional well-being.

Direct exposure to ambient heat likely affects emotional well-being by causing heat stress and exhaustion (Kovats and Hajat, 2008), which is experienced as intrinsically unpleasant (Frederick and Loewenstein, 1999). Heat exposure may also alter mental states through thermo-sensitive physiological processes (Leon and

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Bouchama, 2015; Page et al., 2007). Emotional well-being may diminish because individuals are forced to stay indoors for extended periods, have to alter their daily schedules and face increased cooling expenditures, e.g., due to running air conditioners (Deschênes, 2012). Our outcome measure therefore captures potential well-being losses due to direct heat exposure and opportunity costs caused by heat avoidance.

Our data allow us to explore whether adaptation to heat exposure could lower the adverse effect of heat on emotional well-being. The U.S. represents a good test-case because of its diverse climate conditions, mobile population and available technology. Local climate conditions are a robust predictor of where in the U.S. Americans chose to live (Albouy et al., 2013). At least some Americans chose to live in areas with local climate conditions that optimally fit their preferences, e.g., areas with neither very cold winters nor extremely hot summers. Climate-driven migration therefore represents one mechanism of adaptation (Albouy et al., 2013; Deschênes and Moretti, 2009). Second, heating and cooling technologies like air conditioners are widely available (Barreca et al., 2016) so that individuals can avoid exposure to hazardous temperatures and can adjust indoor climates to subjectively optimal levels.

Residential mobility and technology therefore allow individuals to move to and adapt to local climates. While these conditions exist in other developed countries too, the U.S. is a good test case because climate conditions vary more across regions, which provides useful identifying variation while keeping many other factors, e.g. available technology, constant. We exploit this identifying variation to test whether adaptation to local climates could perhaps mitigate or even eliminate any impact of ambient temperature on emotional well-being.

Finally, the issue of adaptation is relevant to understanding the future impact of global warming on well-being. If further adaptation occurs, the future impact of increased heat exposure due to global climate change may not result in a net well-being loss. Conversely, if we find that heat lowers well-being by the same amount across areas with mild and hot summers, this could be interpreted as evidence that adaptive potentials have been exhausted and that there is little room for further heat adaptation. In this case, it is more likely that the future impact of increased heat exposure will result in a net well-being loss.

2. Materials and methods

We used the Gallup G1K dataset, which is based on telephone surveys of a random sample of 1,000 Americans that is conducted on 350 days per year. Our observation period covers the years 2008–2013. Our analysis included all measures explicitly referencing emotional well-being on the day prior to the day of interview. Specifically, respondents were asked “Did you experience the following feelings a lot of the day yesterday?” before interviewers went through the following list: enjoyment, worry, sadness, stress, anger, and happiness. We also included the following additional questions: “Did you smile or laugh a lot yesterday? ”, “Did you have enough energy to get things done yesterday? ”, “Were you treated with respect all day yesterday? ”, and “Did you feel well-rested yesterday?”. For each item, respondents could chose to answer “yes”, “no”, “don’t know”, or refuse to answer. Individuals in the last two response categories were dropped, reducing sample size by 4%, which resulted in a final sample of 1,854,746 individuals. The items included in the analyses were originally developed to capture hedonic well-being (Kahneman and Krueger, 2006), but are very similar to items used in common epidemiologic self-report mental health scales (see Appendix, p. 7., for further details).

We recoded the well-being measures into binary variables that took the value 1 for “yes” responses indicating the presence of positive feelings or the value 0 for “no” responses indicating the presence of negative feelings, i.e. the value 1 indicates reports of positive or absence of negative feelings. We performed principal component analysis on all ten items. The first component explained 53% of the total variation. Predicted scores of this component form our aggregate index of emotional well-being. After oblique rotation, we obtained three distinct components that jointly explained 74% of the total variation, and which we labeled positive emotions (happiness, enjoyment, smiling/laughter), negative emotions (anger, stress, worry, sadness, not treated with respect), and fatigue (well-rested, enough energy). The predicted scores for these components were also analyzed as dependent variables. All indices are standardized (mean = 0, standard deviation = 1). Further details on the index construction and results from principal components analysis are available in the Appendix (p. 4).

We linked the G1K survey to temperature data using information on the day of interview and respondents’ self-reported zip codes. Respondents’ zip codes were linked to Zip Code Tabulation Areas (ZCTAs) and, in combination with data on interview dates, matched to 24-hour average daily temperature records from the North American Land Data Assimilation System (NLDAS-2) forcing files, which provide hourly estimates of air temperature (K) 2 m above ground level on a $0.125 \times 0.125°$ grid. Air temperature is the main predictor of interest; total hourly precipitation and relative humidity (calculated from temperature, pressure and specific humidity) were included as control variables for robustness checks. For each respondent in our sample, we calculated the daily 24-hour average values of these variables at the centroid of the ZCTA. Our main exposure variable is 24-hour average temperature in respondents’ ZCTA of residence on the day prior to the day of interview, which is the day to which outcome measurements refer.

To model the relationship between temperature and well-being, we used ordinary least squares (OLS) regression with sampling weights provided by Gallup and standard errors adjusted for clustering of respondents within ZCTAs. Because individuals residing in different areas differ in ways that are likely to be correlated with well-being and local temperatures, we control for area of residence fixed effects (Burke et al., 2015). To reduce computation time, rather than controlling for > 32,000 ZCTA fixed effects, we control for commuting zone fixed effects in our baseline specification. Specification checks (see Appendix, p. 16) show that this restriction does not affect temperature estimates. Using information on the county of residence, we identify individual commuting zones, which are similar to Metropolitan Statistical Areas defined by the U.S. Census Bureau, but include rural counties too. We observe 691 commuting zones. The resulting estimates are immune to biases resulting from unmeasured time-invariant determinants of well-being shared by individuals residing in the same commuting zone. Furthermore, seasonal factors, e.g. variation in sunlight exposure (Buscha, 2016), are correlated with well-being and temperature and therefore flexibly controlled for. The modeling approach closely follows recent contributions in climate economics (Burke et al., 2015; Deschênes and Greenstone, 2011).

Specifically, we estimate variants of the following model, where we use subscripts i to denote individuals, j to denote commuting zones ($j = 1, \ldots, 691$), m to denote survey months ($m = 1, \ldots, 12$), s to denote contiguous US states ($s = 1, \ldots, 48$), c to denote calendar weeks ($c = 1, \ldots, 312$) and y to denote calendar years ($y = 2008, \ldots, 2013$):

$$Y_{ijmscy} = \alpha_{jm} + \sum_{k=1}^{7} \beta_k T_k + \lambda_{sy} + \mu_c + X_i \gamma + \varepsilon_{ijmscy}$$