LETTERS
https://doi.org/10.1038/s41562-017-0240-0

nature human behaviour

Corrected: Author correction

Regional ambient temperature is associated with human personality

Wenqi Wei[1,2], Jackson G. Lu[3], Adam D. Galinsky[3], Han Wu[1], Samuel D. Gosling[4,5], Peter J. Rentfrow[6], Wenjie Yuan[1], Qi Zhang[7], Yongyu Guo[8], Ming Zhang[9], Wenjing Gui[1], Xiao-Yi Guo[1], Jeff Potter[10], Jian Wang[11], Bingtan Li[1], Xiaojie Li[1], Yang-Mei Han[1], Meizhen Lv[1], Xiang-Qing Guo[1], Yera Choe[1], Weipeng Lin[12], Kun Yu[13], Qiyu Bai[1], Zhe Shang[14], Ying Han[1] and Lei Wang[1]*

Human personality traits differ across geographical regions[1–5]. However, it remains unclear what generates these geographical personality differences. Because humans constantly experience and react to ambient temperature, we propose that temperature is a crucial environmental factor that is associated with individuals' habitual behavioural patterns and, therefore, with fundamental dimensions of personality. To test the relationship between ambient temperature and personality, we conducted two large-scale studies in two geographically large yet culturally distinct countries: China and the United States. Using data from 59 Chinese cities ($N = 5{,}587$), multilevel analyses and machine learning analyses revealed that compared with individuals who grew up in regions with less clement temperatures, individuals who grew up in regions with more clement temperatures (that is, closer to 22 °C) scored higher on personality factors related to socialization and stability (agreeableness, conscientiousness, and emotional stability) and personal growth and plasticity (extraversion and openness to experience). These relationships between temperature clemency and personality factors were replicated in a larger dataset of 12,499 ZIP-code level locations (the lowest geographical level feasible) in the United States ($N = 1{,}660{,}638$). Taken together, our findings provide a perspective on how and why personalities vary across geographical regions beyond past theories (subsistence style theory, selective migration theory and pathogen prevalence theory). As climate change continues across the world, we may also observe concomitant changes in human personality.

A wealth of evidence suggests that human personality traits differ across geographical regions[1–5]. Such geographical variation in personality has been shown to predict a broad array of psychological, political, economic and health outcomes[3,4,6]. However, one important question remains: What generates these geographical differences in personality?

Humans constantly experience and react to ambient temperature. Because temperature varies markedly across the world, it is conceivable that temperature shapes the fundamental dimensions of personality by affecting the habitual behaviours that underlie personality traits. Temperature may shape personality directly by influencing individual behaviours (for example, exploring outdoors versus staying indoors), and less directly by influencing collective activities (for example, agriculture) that guide individual behaviours[7]. Consequently, regions with different ambient temperatures may result in different patterns of personality traits.

Personality is defined as "the interactive aggregate of personal characteristics that influence an individual's response to the environment"[8]. The hundreds of personality traits used to describe humans are largely captured by five broad dimensions, often called the Big Five: agreeableness, conscientiousness, emotional stability, extraversion, and openness to experience[9]. These five personality factors can be further aggregated into two higher-order factors: 'Alpha' (agreeableness, conscientiousness, and emotional stability), which represents a socialization and stability factor, and 'Beta' (extraversion and openness to experience), which represents a personal growth and plasticity factor[10,11].

We propose that ambient temperature clemency is a key factor that relates to personality. This proposition is rooted in the fact that, as a warm-blooded species, humans have the existential need for thermal comfort[12–15]. Clement (that is, mild) temperatures encourage individuals to explore the outside environment, where both social interactions and new experiences abound; by contrast, when the ambient temperature is either too hot or too cold, individuals are less likely to go outside (for example, to meet up with friends, or to try new activities)[16]. This perspective is consistent with attachment theories, which state that individuals are more likely to explore their environments when they feel psychologically secure[17,18].

Based on this reasoning, we hypothesize that individuals who grow up in more clement temperatures will be higher on both the socialization factor (Alpha) and the personal growth factor (Beta). Regarding the socialization factor Alpha, research has found that personality traits develop partly through social interactions[19,20]. More clement temperatures facilitate social contact[16], for which agreeableness, conscientiousness and emotional stability are important[21]. Moreover, clement temperatures have been shown to enhance

[1]School of Psychological and Cognitive Sciences and Beijing Key Laboratory for Behavior and Mental Health, Peking University, Beijing, China. [2]Center for Biomedical Informatics, College of Medicine, Texas A&M University Health Science Center, Bryan, TX, USA. [3]Columbia Business School, Columbia University, New York, NY, USA. [4]Department of Psychology, University of Texas at Austin, Austin, TX, USA. [5]School of Psychological Sciences, University of Melbourne, Melbourne, Victoria, Australia. [6]Department of Psychology, University of Cambridge, Cambridge, UK. [7]School of Psychology, Liaoning Normal University, Dalian, China. [8]School of Psychology, Nanjing Normal University, Nanjing, China. [9]Department of Psychology, Soochow University, Suzhou, China. [10]Atof Inc., Cambridge, MA, USA. [11]Wisejoy.com, Beijing, China. [12]Department of Human Resource Management, Business School, Nankai University, Tianjin, China. [13]School of Labor and Human Resources, Renmin University of China, Beijing, China. [14]Guanghua School of Management, Peking University, Beijing, China. Wenqi Wei and Jackson G. Lu contributed equally to this work. *e-mail: leiwang@pku.edu.cn

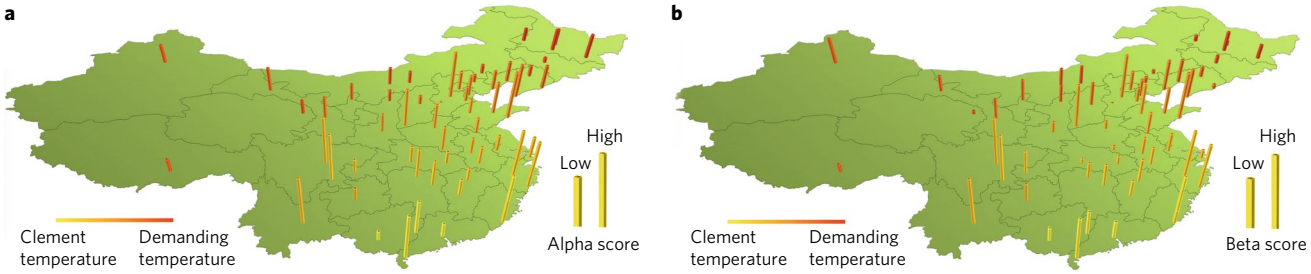

Fig. 1 | Temperature clemency and personality scores of the 59 Chinese continental cities. The location of each city is indicated by a vertical bar. The colour of each bar represents temperature clemency (with lighter colours representing more clement temperatures) and the height represents the corresponding personality score. **a**, Distribution of temperature clemency and Alpha scores. **b**, Distribution of temperature clemency and Beta scores.

positive mood[22] and lead individuals to behave more prosocially[23]. Regarding the personal growth factor Beta, more clement temperatures promote a wider range of activities, which may lead individuals to become more extraverted and open to new experiences[24]. A study of 49 cultures revealed that the mean temperature of a cultural region was positively related to people's perception of how extraverted and open a typical person in that culture is; however, this study did not examine how temperature was related to actual personalities beyond these stereotypical perceptions[25]. In another study of 1,662 Chinese residents[13], individuals from provinces with more clement temperatures scored higher on individualism — a cultural value dimension that is positively correlated with extraversion[26].

Our temperature clemency perspective adds to several key theories that speak to geographical variation in personality[3,12,27]. First, subsistence style theory posits that different subsistence strategies can produce geographical differences in personality-related cultural constructs[7,28]; for example, members of farming and fishing communities, which value harmonious social interdependence, show greater holistic tendencies than members of herding communities, which value individual decision making and social independence[28]. Second, the selective migration theory of personality proposes that selective migration patterns can produce geographical differences in personality. According to this view, people selectively migrate to regions that fulfill and reinforce their physical and psychological needs[3]. Third, the pathogen prevalence theory of personality suggests that, as a self-protective mechanism, individuals exhibit lower extraversion and openness to experiences in regions with a higher prevalence of disease-causing pathogens[29].

There is ample evidence that ambient temperature affects agricultural activities (when and what to farm)[28], individuals' migration decisions[3], and pathogen prevalence[30]. Thus, ambient temperature likely has important explanatory power for geographical variation in personality. Overall, our temperature clemency perspective of personality offers a mechanism for why and how macro-level environmental forces might shape individual-level personality.

Several methodological problems have plagued the few investigations into geographical differences in personality. Most notably, previous research has largely focused on personality differences across broad geographical regions (for example, across countries)[1–5], which makes it difficult to eliminate the confounding effects of other variables, such as between-country cultural differences. To isolate the effects of ambient temperature from such confounding variables, the use of subject samples from within a single country is preferable. Of course, that single country must be of substantial geographical size to capture sufficient variance in temperature. A related issue with examining personality at the country level is that analyses at such a broad level may obscure meaningful within-country regional variances in temperature and personality. Thus, it is important to analyse the effects of temperature on personality at the lowest geographical levels feasible — that is, at the city level or even the ZIP-code level — within which variances in both temperature and personality differences will be minimal.

To overcome these methodological concerns, we conducted two separate, large-scale studies within two geographically large yet culturally distinct countries: China and the United States. Given that the period from birth to adulthood is crucial for personality development[31], for each participant, we collected meteorological data of the geographical location where he or she grew up.

In study 1, a total of 5,587 university students (42.4% females, mean age = 22.07 years, s.d. age = 2.05) who were born and raised in 59 Chinese cities completed a personality survey online in return for individualized feedback (see Supplementary Information for details). These cities covered all provincial-level administrative divisions in continental China (Fig. 1; Supplementary Table 1). To preclude reverse causality, in which certain personalities may cause individuals to migrate to cities with certain temperatures, we limited our sample to students who had spent their pre-college youth in their birthplace. To rule out another alternative explanation — that parents with certain personalities chose to migrate to a certain city and then gave birth to children who resemble their personalities — we further limited the sample to participants whose birthplace matched their ancestral home (that is, *jiguan*, the home of their patrilineal ancestors). Importantly, all results remained substantively unchanged without these exclusion criteria.

In line with past research[13,14], we computed a 'temperature clemency' variable, −|mean temperature − 22 °C|, which measures the extent to which a city's ambient temperature is close to the psychophysiological comfort optimum of 22 °C (about 72 °F). Thus, the further a city's temperature is from 22 °C, the less clement it is.

At the city level, temperature clemency was positively correlated with both Alpha and Beta, as well as with each of the Big-Five personality factors ($P < 0.05$ for all personality factors except agreeableness, for which $P = 0.160$; see Supplementary Table 5). Figure 1 maps the temperature clemency of each city with Alpha and Beta, respectively. By contrast, air pressure or wind speed was not significantly correlated with Alpha, Beta or any of the Big-Five personality factors ($P > 0.23$ for all personality factors).

Because the 5,587 participants (level 1) were nested within the 59 cities (level 2), we conducted multilevel analyses to account for the statistical dependence within each city and the fact that different cities had different sample sizes (see Supplementary Tables 6–12). Consistent with the city-level correlational results, temperature clemency was positively associated with Alpha, Beta, and each of the Big-Five personality factors, even after accounting for individual -level control variables age, gender, and acquiescent response style ($P < 0.05$ for all personality factors) and city-level control variables population density, gross domestic product (GDP) per capita, average annual rice-farming area, average annual wheat-farming area, influenza incidence, and the standard deviation of the mean temperature ($P < 0.01$ for all personality factors).

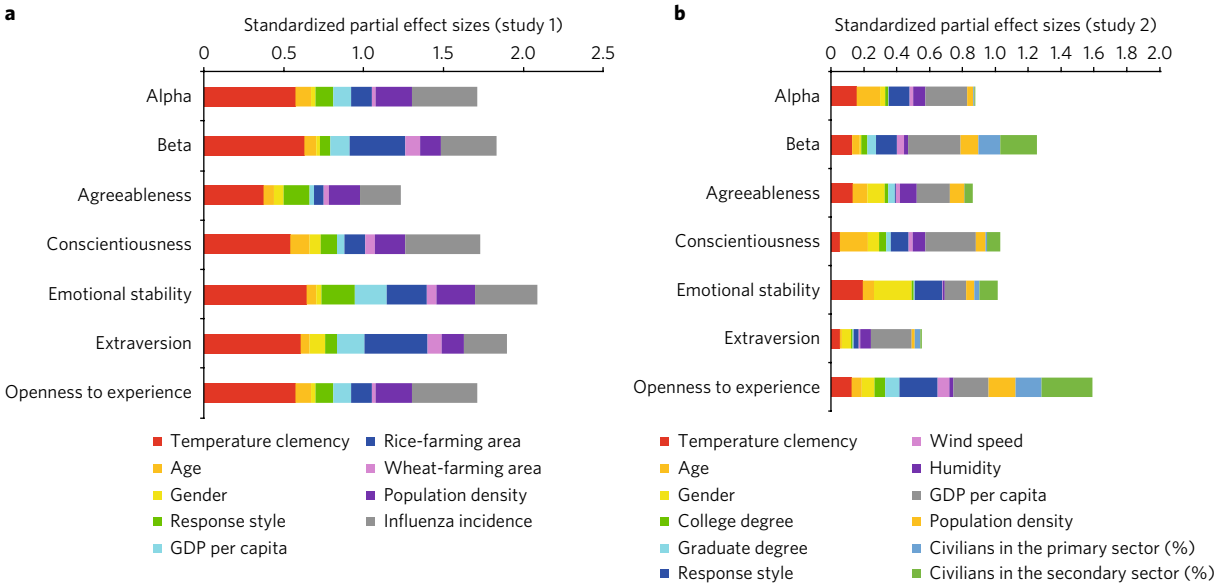

Fig. 2 | Standardized partial effect sizes of the predictor variables in the full multilevel models (calculated by *t*-to-*r* transformation). a, Study 1 (the sample from China). **b**, Study 2 (the sample from the United States).

As a robustness check, we also computed another version of temperature clemency using –(|minimum temperature – 22 °C| + |maximum temperature – 22 °C|)[13,14]. All results remained substantively unchanged when we used this measure as the predictor in multilevel analyses ($P < 0.01$ for all personality factors) (see Supplementary Table 13). Figure 2a compares the effect sizes (calculated by *t*-to-*r* transformation) of all the predictor variables and highlights the importance of temperature clemency in the Chinese sample.

In addition to multilevel analyses, we conducted machine-learning analyses to explore which of the variables were likely important predictors of personality (see Supplementary Figs. 8–12). Consistent with the results of multilevel modelling, conditional random forest analyses reliably identified temperature clemency to be an important predictor of each of the seven personality factors. For analytical details, see Supplementary Information.

In support of our temperature clemency perspective of personality, study 1 revealed a relationship between ambient temperature clemency and personality among Chinese participants: individuals who grew up in cities with milder temperatures scored higher on both the socialization factor (Alpha) and the personal growth factor (Beta) of personality, as well as on each of the Big-Five personality factors.

Study 2 sought to extend study 1 in several important ways. First, we investigated whether the effects of temperature clemency on personality factors would replicate in the United States, another geographically large yet culturally distinct country. Second, we more closely scrutinized these effects by collecting data at the lowest geographical level feasible: the ZIP-code level. Third, to examine the robustness of these effects, we used another well-validated measure of the Big-Five personality factors (see Supplementary Information). Fourth, we used an even larger participant sample ($N > 1.6$ million) that was representative of the general US population in terms of age, social class, and education levels (age range = 16–60 years, as opposed to only university students).

Study 2 involved 1,660,638 Americans who participated in return for a customized personality evaluation (65.3% female, mean age = 27.05 years, s.d. age = 11.00, 17.0% with a college degree, 9.44% with a graduate degree) (for details, see Supplementary Information). Participants reported the US ZIP code where they spent most of their youth (12,499 US ZIP codes in 8,102 cities). As in study 1, we operationalized ambient temperature as being 'more clement' to the extent that it is closer to 22 °C.

Replicating the Chinese data, multilevel analyses (see Supplementary Tables 17–23) revealed that temperature clemency was positively associated with Alpha, Beta, and each of the Big-Five personality factors after accounting for individual-level control variables age, gender, education, and acquiescent response style ($P < 0.015$ for all personality factors) and ZIP-code level control variables humidity, wind speed, population density, GDP per capita, the percentages of civilians employed in the primary sector (for example, agriculture), in the secondary sector (for example, construction, and manufacturing), and in the tertiary sector (that is, service) ($P < 0.001$ for all personality factors). Importantly, temperature clemency was the only meteorological variable that was consistently associated with each of the seven personality factors; for example, neither humidity nor wind speed was significantly associated with emotional stability ($P > 0.25$ for both humidity and wind speed).

Figure 2b compares the effect sizes (calculated by *t*-to-*r* transformation) of all the predictor variables and highlights the importance of temperature clemency in the sample from the United States.

Consistent with the results of multilevel modelling, machine-learning analyses using conditional random forest again reliably identified temperature clemency to be an important predictor of each of the seven personality factors (see Supplementary Figs. 13–17).

In summary, two large-scale studies from China and the United States found that the ambient temperature during an individual's youth was related to the key dimensions of personality: individuals who grew up in more clement regions scored higher on both the socialization factor (Alpha) and the personal growth factor (Beta) of personality, as well as on each of the Big-Five personality factors. These effects were robust when controlling for various factors that might affect personality-related constructs: selective migration, individual response style, demographic factors (age, gender, and education), socioeconomic factors (population density, GDP per capita, rice-farming area, and wheat-farming area), ecological factors (pathogen prevalence), and other meteorological

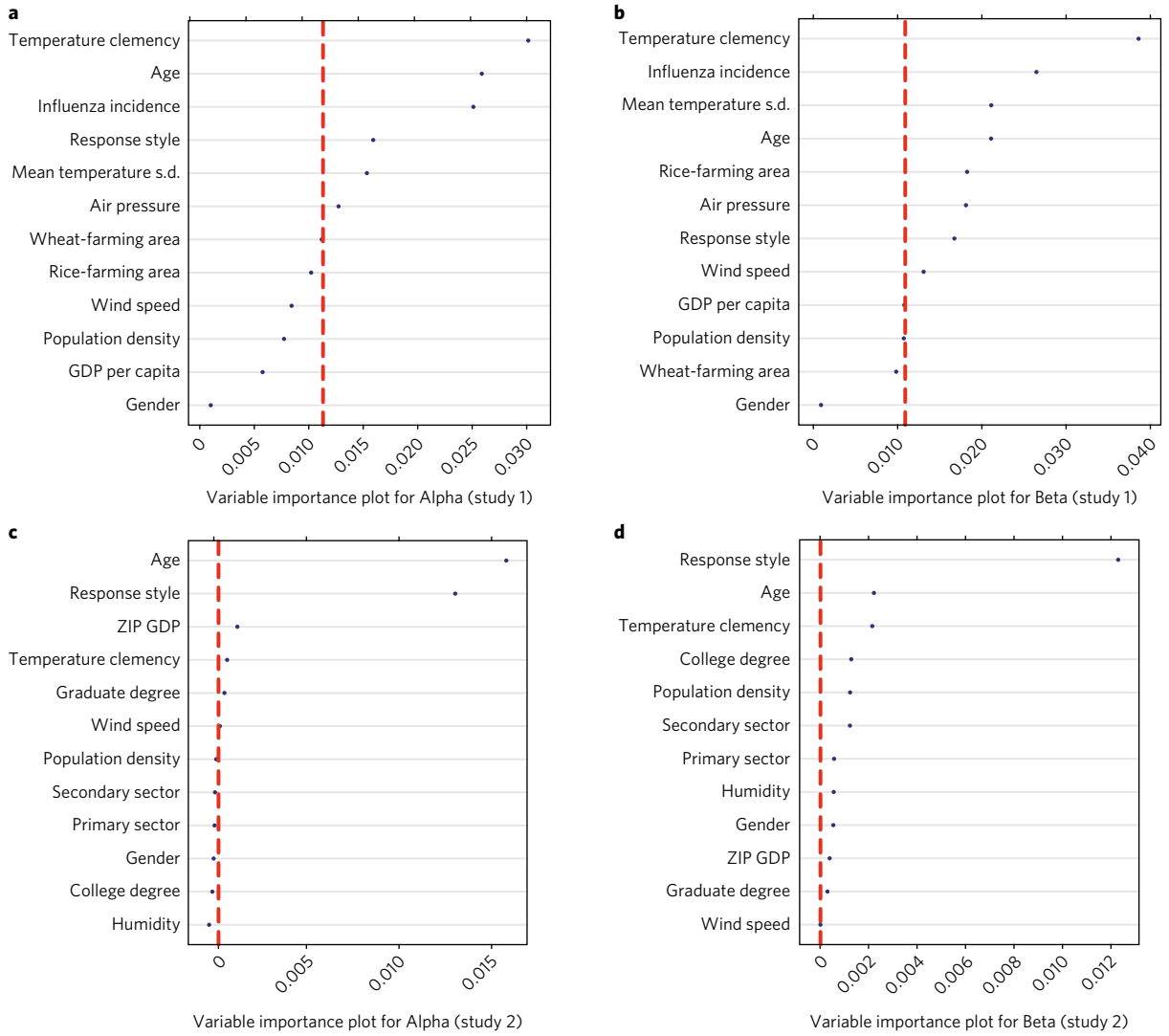

Fig. 3 | Variable importance plots of the predictor variables in machine-learning analyses. a, Alpha (study 1). **b**, Beta (study 1). **c**, Alpha (study 2). **d**, Beta (study 2). The variables to the right of the red dashed line are statistically significant in predicting personality.

factors (air pressure, humidity, and wind speed). It is particularly telling that our large datasets from two geographically large yet culturally distinct countries provided converging evidence. Taken together, these findings are consistent with our temperature clemency perspective of personality: growing up in temperatures that are close to the psychophysiological comfort optimum encourages individuals to explore the outside environment, thereby influencing their personalities.

The present research adds to past theories and findings on how socioecological factors (selective migration, subsistence strategies and pathogen prevalence) are associated with human personality. Theoretically, we point to a probable antecedent of these factors: ambient temperature. Empirically, we explicitly controlled for selective migration, subsistence strategies, and pathogen prevalence in the Chinese sample. Moreover, whereas past studies focused on broad geographical levels (for example, countries), we examined the effects of ambient temperature on personality at the lowest geographical levels feasible (city and ZIP-code levels).

Although our temperature clemency perspective of personality offers a mechanism for why and how macro-level environmental forces might influence individual-level personality, we note that temperature clemency is one of many factors associated with human personality. In addition, standardized partial effect size plots (Fig. 2) and variable importance plots (Fig. 3; Supplementary Figs. 8–17) suggest that temperature clemency might be more associated with the personalities of Chinese individuals than the personalities of American individuals. Future research could further examine such cross-cultural differences.

In light of the present findings, it is also important to highlight social thermoregulation theory[17,32], which posits that people seek 'social warmth' in a cold environment because an important function of social relationships is to facilitate the regulation of body temperature. For example, a recent study found that, compared with residents of warmer climates, residents of colder climates reported a wider variety of social ties[33]. Importantly, social thermoregulation theory and our temperature clemency perspective of personality do not necessarily oppose each other. Although social thermoregulation theory suggests that a cold climate compels people to seek social warmth, our findings suggest that a clement climate encourages people to explore the outside environment to engage in more social activities and new experiences that are conducive to socialization (Alpha) and growth (Beta).

While much is known about the effects of temperature on human health and performance, the present research examined its

relationship with personality. Our findings offer insights into why people in different regions of the world exhibit different personality traits and behaviours. As climate change continues across the world, we may also observe concomitant changes in human personality. Of course, questions about the size and extent of these changes await future investigation.

Methods

For analytical details of multilevel and machine-learning analyses, see Supplementary Information.

Study 1. This research was approved by the Institutional Review Board of Peking University. All participants completed the 40-item Mini-Markers Scale that assessed the Big-Five personality factors, each of which consisted of eight items ($\omega_{t[\text{agreeableness}]}=0.79$, $\omega_{t[\text{conscientiousness}]}=0.88$, $\omega_{t[\text{emotional stability}]}=0.85$, $\omega_{t[\text{extraversion}]}=0.83$, $\omega_{t[\text{openness to experience}]}=0.88$) (see Supplementary Information). Based on the personality literature[10,11], we then further aggregated the Big-Five personality factors into the higher-level factors of Alpha (agreeableness, conscientiousness, and emotional stability) and Beta (extraversion and openness to experience), both of which demonstrated high levels of internal consistency ($\omega_{t[\text{Alpha}]}=0.89$, $\omega_{t[\text{Beta}]}=0.90$).

For each of the 59 cities, the China Meteorological Administration provided us with city-level data of five meteorological indices across the latest available 40 years (1971–2010): average annual mean ambient temperature (2.2 to 23.3 °C), average annual minimum ambient temperature (−3.0 to 20.8 °C), average annual maximum ambient temperature (7.8 to 27.8 °C), average annual air pressure, and average annual wind speed. In line with past research[13,14,34,35], we computed a 'temperature clemency' variable, −|mean temperature − 22 °C|, which measures the extent to which a city's ambient temperature is close to the psychophysiological comfort optimum of 22 °C (about 72 °F). Thus, the further a city's temperature is from 22 °C, the less clement it is.

In light of prior research on geographical differences in personality (for example, subsistence style theory and pathogen prevalence theory), we also collected pertinent city-level control variables for at least 10 years that overlapped with participants' childhood: GDP per capita, population density, average annual rice-farming area, average annual wheat-farming area, and influenza incidence (see Supplementary Information). To reduce the effect of idiosyncrasies of any particular year, we computed the mean value across those years for each of these control variables. Moreover, we computed an 'acquiescent response style' score for each participant based on their responses to the personality items of the Mini-Markers Scale; this variable controlled for individual differences in response style, because individuals from regions with more clement temperatures might consistently agree (yea-saying) or consistently disagree (nay-saying) with questionnaire items regardless of their content[36,37]. Finally, because temperature fluctuation might also affect personality (over and above mean temperature), we also controlled for the standard deviation of mean temperature for each city.

Study 2. This research was approved by the Institutional Review Board of the University of Texas. Each participant completed the 44-item Big-Five Inventory ($\omega_{t[\text{agreeableness}]}=0.84$, $\omega_{t[\text{conscientiousness}]}=0.86$, $\omega_{t[\text{emotional stability}]}=0.88$, $\omega_{t[\text{extraversion}]}=0.91$, $\omega_{t[\text{openness to experience}]}=0.84$) (see Supplementary Information). As with the Chinese data, we aggregated the Big-Five personality factors into the higher-level Alpha and Beta, both of which demonstrated high levels of internal consistency ($\omega_{t[\text{Alpha}]}=0.90$, $\omega_{t[\text{Beta}]}=0.86$).

In addition, participants reported the US ZIP code where they spent most of their youth (12,499 US ZIP codes in 8,102 cities). For each ZIP code, we collected the following meteorological variables: average annual mean ambient temperature, average annual humidity, and average annual wind speed (see Supplementary Information). As in study 1, we operationalized ambient temperature as being 'more clement' to the extent that it is closer to 22 °C. To control for pertinent economic variables, we also collected ZIP-code level data on GDP per capita, population density, the percentages of civilians employed in the primary sector (for example, agriculture), in the secondary sector (for example, construction and manufacturing), and in the tertiary sector (that is, service). As in study 1, we again computed an 'acquiescent response style' variable to control for individual differences in response style.

Life Sciences Reporting Summary. Further information on experimental design is available in the Life Sciences Reporting Summary.

Code availability. Analyses were conducted in R and Stata. All code is available upon request.

Data availability. Personality data are available from the corresponding author upon request.

Received: 15 March 2017; Accepted: 11 October 2017;
Published online: 27 November 2017

References

1. Allik, J. & McCrae, R. R. Toward a geography of personality traits: patterns of profiles across 36 cultures. *J. Cross Cult. Psychol.* **35**, 13–28 (2004).
2. McCrae, R. R. & Terracciano, A. Personality profiles of cultures: aggregate personality traits. *J. Pers. Soc. Psychol.* **89**, 407–425 (2005).
3. Rentfrow, P. J., Gosling, S. D. & Potter, J. A theory of the emergence, persistence, and expression of geographic variation in psychological characteristics. *Perspect. Psychol. Sci.* **3**, 339–369 (2008).
4. Rentfrow, P. J. & Jokela, M. in *The Praeger Handbook of Personality Across Cultures* Vol. 1 (ed. Church, A. T.) 225–249 (Praeger, Santa Barbara, CA, 2017).
5. Schmitt, D. P., Allik, J., McCrae, R. R. & Benet-Martínez, V. The geographic distribution of Big Five personality traits patterns and profiles of human self-description across 56 nations. *J. Cross Cult. Psychol.* **38**, 173–212 (2007).
6. Obschonka, M., Schmitt-Rodermund, E., Silbereisen, R. K., Gosling, S. D. & Potter, J. The regional distribution and correlates of an entrepreneurship-prone personality profile in the United States, Germany, and the United Kingdom: a socioecological perspective. *J. Pers. Soc. Psychol.* **105**, 104–122 (2013).
7. Talhelm, T. et al. Large-scale psychological differences within China explained by rice versus wheat agriculture. *Science* **344**, 603–608 (2014).
8. Guilford, J. P. *Personality* 383–384 (McGraw-Hill, New York, NY, 1959).
9. Goldberg, L. R. The development of markers for the Big-Five factor structure. *Psychol. Assess.* **4**, 26–42 (1992).
10. Digman, J. M. Higher-order factors of the Big Five. *J. Pers. Soc. Psychol.* **73**, 1246–1256 (1997).
11. DeYoung, C. G. Higher-order factors of the Big Five in a multi-informant sample. *J. Pers. Soc. Psychol.* **91**, 1138–1151 (2006).
12. Van de Vliert, E. in *The Praeger Handbook of Personality Across Cultures* Vol. 3 (ed. Church, A. T.) 117–148 (Praeger, Santa Barbara, CA, 2017).
13. Van de Vliert, E., Yang, H., Wang, Y. & Ren, X. Climato-economic imprints on Chinese collectivism. *J. Cross Cult. Psychol.* **44**, 589–605 (2013).
14. Van de Vliert, E. Climato-economic habitats support patterns of human needs, stresses, and freedoms. *Behav. Brain Sci.* **36**, 465–521 (2013).
15. Van de Vliert, E. in *Advances in Culture and Psychology* Vol. 3 (eds Gelfand, M. J., Chiu, C. & Hong, Y.) 227–282 (Oxford Univ. Press, Oxford, 2013).
16. Cohen, L. E. & Felson, M. Social change and crime rate trends: a routine activity approach. *Am. Sociol. Rev.* **44**, 588–608 (1979).
17. IJzerman, H. et al. A theory of social thermoregulation in human primates. *Front. Psychol.* **6**, 464 (2015).
18. Ainsworth, M. D. S. & Bell, S. M. Attachment, exploration, and separation: illustrated by the behavior of one-year-olds in a strange situation. *Child Dev.* **41**, 49–67 (1970).
19. Caspi, A. & Roberts, B. W. Personality development across the life course: the argument for change and continuity. *Psychol. Inq.* **2**, 49–66 (2001).
20. Triandis, H. C. & Suh, E. M. Cultural influences on personality. *Annu. Rev. Psychol.* **53**, 133–160 (2002).
21. Chiaburu, D. S., Oh, I.-S., Berry, C. M., Li, N. & Gardner, R. G. The five-factor model of personality traits and organizational citizenship behaviors: a meta-analysis. *J. Appl. Psychol.* **96**, 1140–1166 (2011).
22. Cunningham, M. R. Weather, mood, and helping behavior: quasi experiments with the sunshine samaritan. *J. Pers. Soc. Psychol.* **37**, 1947–1956 (1979).
23. Fetterman, A. K., Wilkowski, B. M. & Robinson, M. D. On feeling warm and being warm: daily perceptions of physical warmth fluctuate with interpersonal warmth. *Soc. Psychol. Person. Sci.* http://doi.org/10.1177%2F1948550617712032 (2017).
24. Tucker, P. & Gilliland, J. The effect of season and weather on physical activity: a systematic review. *Public Health* **121**, 909–922 (2007).
25. McCrae, R. R., Terracciano, A., Realo, A. & Allik, J. Climatic warmth and national wealth: some culture-level determinants of national character stereotypes. *Eur. J. Pers.* **21**, 953–976 (2007).
26. Hofstede, G. & McCrae, R. R. Personality and culture revisited: linking traits and dimensions of culture. *Cross Cul. Res.* **38**, 52–88 (2004).
27. Gelfand, M. J., Harrington, J. & Fernandez, J. in *The Praeger Handbook of Personality Across Cultures* Vol. 3 (ed. Church, A. T.) 207–236 (Praeger, Santa Barbara, CA, 2017).
28. Uskul, A. K., Kitayama, S. & Nisbett, R. E. Ecocultural basis of cognition: farmers and fishermen are more holistic than herders. *Proc. Natl Acad. Sci. USA* **105**, 8552–8556 (2008).
29. Murray, D. R. & Schaller, M. in *The Praeger Handbook of Personality Across Cultures* Vol. 3 (ed. Church, A. T.) 87–116 (Praeger, Santa Barbara, CA, 2017).
30. Elliot, S. L., Blanford, S. & Thomas, M. B. Host–pathogen interactions in a varying environment: temperature, behavioural fever and fitness. *P. R. Soc. B Biol. Sci.* **269**, 1599–1607 (2002).
31. Roberts, B. W., Walton, K. E. & Viechtbauer, W. Patterns of mean-level change in personality traits across the life course: a meta-analysis of longitudinal studies. *Psychol. Bull.* **132**, 1–25 (2006).
32. IJzerman, H. & Hogerzeil, L. in *The Oxford Handbook of Human Essence* (eds van Zomeren, M. & Dovidio, J. F.) 83–94 (Oxford Univ. Press, Oxford, 2017).

33. IJzerman, H. *et al*. The human penguin project: social integration protects against cold climates. Preprint at https://doi.org/10.17605/OSF.IO/6B7NE (2017).
34. Van de Vliert, E. Climatoeconomic roots of survival versus self-expression cultures. *J. Cross Cult. Psychol.* **38**, 156–172 (2007).
35. Fischer, R. & Van de Vliert, E. Does climate undermine well-being? A 58-nation study. *Pers. Soc. Psychol. Bull.* **37**, 1031–1041 (2011).
36. Soto, C. J., John, O. P., Gosling, S. D. & Potter, J. The developmental psychometrics of big five self-reports: acquiescence, factor structure, coherence, and differentiation from ages 10 to 20. *J. Pers. Soc. Psychol.* **94**, 718–737 (2008).
37. Steinmetz, J. & Posten, A.-C. Physical temperature affects response behavior. *J. Exp. Soc. Psychol.* **70**, 294–300 (2017).

Acknowledgements

This research is partly supported by the National Science Foundation of China (NSFC) grant no. 91224008 and no. 91324201 and the Foundation of Beijing Key Laboratory of Behavior and Mental Health grant no. Z151100001615053 to L.W. We are grateful to V. Benet-Martínez, M. Morris, and E. Page-Gould for their valuable insights, and C. Chen, J. Chen, X. Di, Y. Huang, J. Jiang, M. Jiang, D. Li, M. Li, C. Liu, Y. Ma, J. Ma, L. Peng, L. Qiao, L. Ren, P. Wang, H. Yu, J. Zhang, M. Zhou and other graduate students working with L.W. for their help with data collection. We thank the China Meteorological Administration for providing the climate data and the Chinese Center for Disease Control and Prevention for providing the disease data. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Author contributions

L.W. conceived the core research idea. W.W., J.G.L., A.D.G. and L.W. designed the research. W.W., J.G.L., H.W., S.D.G., P.J.R., W.Y., Q.Z., Y.G., M.Z., W.G., X.Y.G., J.P., J.W., B.L., X.L., Y.M.H., M.L., X.Q.G., Y.C., W.L., K.Y., Q.B., Z.S., Y.H., and L.W. performed the research. W.W., J.G.L., H.W., W.Y. and L.W. analysed the data. W.W., J.G.L., A.D.G., S.D.G., P.J.R. and L.W. wrote the paper.

Competing interests

The authors declare no competing interests.

Additional information

Supplementary information is available for this paper at https://doi.org/10.1038/s41562-017-0240-0.

Reprints and permissions information is available at www.nature.com/reprints.

Correspondence and requests for materials should be addressed to L.W.

Publisher's note: Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

nature research

Corresponding author(s): Lei Wang

☐ Initial submission ☐ Revised version ☒ Final submission

Life Sciences Reporting Summary

Nature Research wishes to improve the reproducibility of the work that we publish. This form is intended for publication with all accepted life science papers and provides structure for consistency and transparency in reporting. Every life science submission will use this form; some list items might not apply to an individual manuscript, but all fields must be completed for clarity.

For further information on the points included in this form, see Reporting Life Sciences Research. For further information on Nature Research policies, including our data availability policy, see Authors & Referees and the Editorial Policy Checklist.

Experimental design

1. Sample size

Describe how sample size was determined.

For the purpose of multilevel analysis, we ensured that there were at least 30 participants nested within each city or ZIP-code.

2. Data exclusions

Describe any data exclusions.

Study 1: To preclude reverse causality, where certain personalities may cause individuals to migrate to cities with certain temperatures, we limited our sample to students who had spent the entirety of their pre-college youth in their birthplace. To rule out another alternative explanation—that parents with certain personalities chose to migrate to a certain city and then gave birth to children who resemble their personalities—we further limited the sample to participants whose birthplace matched their ancestral home (i.e., jiguan, the home of their patrilineal ancestors). Importantly, all results remained substantively unchanged without these exclusion criteria.
Study 2: We applied the following criteria. First, consistent with the Chinese data, participants must have chosen the United States as the country in which they spent most of their youth. Second, participants must have provided a meaningful U.S. ZIP code for the question "What is the ZIP-code/postal code of the place where you spent most of your youth?" Third, the ZIP code provided must have correctly matched their answer to the question "What state did you spend most of your youth?" Fourth, for the purpose of multilevel modeling15, we only included youth ZIP codes that had at least 30 participants (as in the Chinese data). Fifth, in line with prior work28, we only included participants between 16 to 60 years old due to the concern that older participants might be particularly susceptible to self-selection bias. Sixth, we only included participants who completed the study in English (as opposed to Dutch, German, or Spanish). Seventh, participants must have responded with "yes" to the question "Did you answer truthfully on all of these questions?" Lastly, participants must have responded with "no" to the question "Have you ever previously filled out this particular questionnaire on this site?"

3. Replication

Describe whether the experimental findings were reliably reproduced.

The results were reliably reproduced across the two samples.

4. Randomization

Describe how samples/organisms/participants were allocated into experimental groups.

N/A

5. Blinding

Describe whether the investigators were blinded to group allocation during data collection and/or analysis.

N/A

Note: all studies involving animals and/or human research participants must disclose whether blinding and randomization were used.

6. Statistical parameters

For all figures and tables that use statistical methods, confirm that the following items are present in relevant figure legends (or in the Methods section if additional space is needed).

n/a	Confirmed
☐	☒ The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement (animals, litters, cultures, etc.)
☐	☒ A description of how samples were collected, noting whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☒	☐ A statement indicating how many times each experiment was replicated
☐	☒ The statistical test(s) used and whether they are one- or two-sided (note: only common tests should be described solely by name; more complex techniques should be described in the Methods section)
☐	☒ A description of any assumptions or corrections, such as an adjustment for multiple comparisons
☐	☒ The test results (e.g. *P* values) given as exact values whenever possible and with confidence intervals noted
☐	☒ A clear description of statistics including central tendency (e.g. median, mean) and variation (e.g. standard deviation, interquartile range)
☒	☐ Clearly defined error bars

See the web collection on statistics for biologists for further resources and guidance.

Software

Policy information about availability of computer code

7. Software

Describe the software used to analyze the data in this study.	We used R and Stata to analyze the data.

For manuscripts utilizing custom algorithms or software that are central to the paper but not yet described in the published literature, software must be made available to editors and reviewers upon request. We strongly encourage code deposition in a community repository (e.g. GitHub). *Nature Methods* guidance for providing algorithms and software for publication provides further information on this topic.

Materials and reagents

Policy information about availability of materials

8. Materials availability

Indicate whether there are restrictions on availability of unique materials or if these materials are only available for distribution by a for-profit company.	No unique materials are used.

9. Antibodies

Describe the antibodies used and how they were validated for use in the system under study (i.e. assay and species).	N/A

10. Eukaryotic cell lines

a. State the source of each eukaryotic cell line used.	N/A
b. Describe the method of cell line authentication used.	N/A
c. Report whether the cell lines were tested for mycoplasma contamination.	N/A
d. If any of the cell lines used are listed in the database of commonly misidentified cell lines maintained by ICLAC, provide a scientific rationale for their use.	N/A

Animals and human research participants

Policy information about studies involving animals; when reporting animal research, follow the ARRIVE guidelines

11. Description of research animals

Provide details on animals and/or animal-derived materials used in the study.	N/A

Policy information about studies involving human research participants

12. Description of human research participants

Describe the covariate-relevant population characteristics of the human research participants.	For study 1, we had 5,587 participants from 59 Chinese cities, with 42.4% females, Mage = 22.07, SDage = 2.05; and for study 2, we had 1,660,638 participants from 12,499 ZIP codes of the United States (65.3% female; Mage = 27.05 years, SDage = 11.00; 17.0% with a college degree, 9.44% with a graduate degree).