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# Invited Perspective: Stranger Danger—Health-Damaging Variable Temperatures

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Is it true that that which is unfamiliar is the most dangerous? Comparisons of minimum mortality temperatures around the world suggest this may be the case. For example, the average daily temperature associated with lowest mortality is 19°C in Stockholm, in comparison with 26°C in Taipei and 30°C in Bangkok.[1] Temperatures that are unusually high for colder parts of the world (e.g., Stockholm) can increase mortality among residents, unlike the same temperature in warmer locations (e.g., Bangkok).[1]

It is not difficult to understand why health-damaging heat or dangerously cold conditions vary from one setting to another, depending on what is commonly experienced. Possible reasons include physiological acclimation, environmental modifications, and personal behaviors based on prior experience and local knowledge. Crossing borders can be risky. One of us flew from Auckland (latitude 37°S) to Umeå, Sweden (latitude 46°N) in January. I knew about hemispheres and seasons but reasoned that in an age of heated airports and taxis, winter clothes could stay in my checked luggage until I reached my hotel. So it was disconcerting when 10 min before landing everyone else on the plane pulled heavy fur coats, massive woolly hats, and mittens out of the overhead compartments. When the door opened, the reason became clear. Air bridges had not yet come to Umeå, the temperature outside was deep in frostbite territory, and I was dressed well for a New Zealand summer.

Much has been written about climate variability, the threats it poses, the influence of long-term climate change, how this variability may create conditions beyond the range of individuals' past experience, and ways to reduce the associated risks. Variability occurs on many scales that affect its impacts and how it can be measured and includes acute contrasts (e.g., hour to hour), long-term variations (e.g., decadal), and much in between.[2] High-frequency variability (e.g., diurnal temperature range) may be the exposure of choice for investigations of particular disease outcomes and physiological changes. Studies of acute changes are less likely to be confounded (especially when it is possible to use person-based crossover study designs). However, it is difficult to allow for suitable time lags, and mortality displacement is more likely to be an issue than in studies of long-term exposures.

In a similar vein, epidemiologists argued over 20 y ago that accurate assessment of the full burden of ill health attributable to poor air quality depends on studies of long-term exposure to air pollution.[3] The choice of scale for measurement of exposure is not straightforward. For instance, what is meant by "long-term"? No one actually experiences the 6-month mean air quality (or temperature). Because the response of human physiology to heating and cooling is not linear, occasional extreme temperatures may matter more for health than long-term average conditions or frequent minor fluctuations. Whether exposures are evaluated over a daily timescale or longer will determine the extent to which these extremes are accounted for. In other words, we believe, a few days of extreme high temperatures will have little influence on the long-term mean temperature but may elevate total mortality substantially.

In this issue of *Environmental Health Perspectives*, Healy et al.[4] investigated the effects of absolute temperature and temperature variability within the warm and cold halves of the year in the contiguous United States. Their study employed a complex cluster analysis that gathered ZIP codes with similar socioeconomic and climate characteristics to control for confounding. The authors then assessed the associations between deaths in U.S. citizens age 65 y and older (the Medicare population) and the mean and standard deviation in daily temperatures.

In their analysis, Healy et al. found that mortality rates were higher when daily average temperatures varied more, and that this effect was more pronounced in the warmer 6 months of the year. Previous research identified strong relationships between absolute temperature and mortality.[5] Unexpectedly, the analysis by Healy et al.—which assessed the influence of variability and absolute temperatures independently—identified no such relationship in either the warm or cold seasons. The authors recognized that this finding is likely a consequence of study design.

Successful climate change adaptation requires that climate variability be managed, in particular the extreme conditions that generate acute impacts. For example, changes to the built environment may protect against unusual cold and heat; better insulation of homes and access to artificial cooling indoors very likely contributed to the reduction in temperature-related mortality in Britain in the 20th century.[6] But dealing with variability in the 21st century will require new strategies. Once-rare high temperatures are becoming commonplace, and extreme temperature records are regularly broken. Moreover, compounding factors, such as intensifying tropical cyclones, increasing susceptibility to heat-related diseases (which may be a consequence of aging populations), and diminishing effectiveness of interventions (such as air conditioning) create new challenges for policymakers and health practitioners.[7,8]

Difficult does not mean impossible; there are many ways to adapt to a variable climate. Agroforestry, when done well, provides such a capacity. Combining trees and shrubs with crop and livestock production can both mitigate climate change through carbon sequestration and buffer farms against climate variability (e.g., floods, droughts, unexpected swings in temperature). But often there are trade-offs involved. For example, trees that are commonly planted on West African farms—such as *Vitellaria paradoxa*, the source of shea butter—may reduce crop yields when rainfall is ample because they cast shade, but these trees are popular because they provide alternative sources of income in dry spells.[9] However, if dry spells occur frequently or extend from one year to the next, or if low rainfall is accompanied by

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high temperatures, then old patterns of planting and harvesting forest products may no longer be fit for purpose.

To understand the impacts of climate change on human health, we need a strong grasp of the complexities of temperature variability. Changes in temperature variability mediate the impacts of rising mean temperatures, and climate projections suggest that changes in the variance and skewness of temperatures will differ between regions.[10] So, a location with lower average temperatures but growing variability (or a more positively skewed temperature distribution) may have the same number of hot days—and therefore similar heat-related mortality—as a location with higher mean temperature but lower temperature variability. Future studies might build on the work by Healy et al. to explore these dynamics.

Current climate action is far short of that needed to meet the Paris Agreement's target of limiting warming to 1.5°C above preindustrial levels; the United Nations Environment Programme's 2022 Emissions Gap Report projected an average global temperature rise of 2.8°C above preindustrial levels by 2100 under existing policies.[11] The world faces a dangerously variable and rapidly changing climate. To minimize the negative impacts of climate change, we need to gain a better understanding of the consequences for human health and then put this knowledge into action.

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