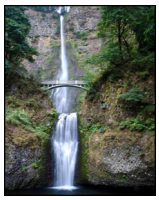
Journal of Environmental Psychology 60 (2018) 21–26

Contents lists available at ScienceDirect

Journal of Environmental Psychology

journal homepage: www.elsevier.com/locate/jep



Climate change is the world's greatest threat – In Celsius or Fahrenheit?

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ARTICLE INFO

Handling Editor: Florian Kaiser

Keywords:
Climate change
Numerosity
Goal pursuit
Scientific communication

ABSTRACT

In two experiments, participants who were told that the Earth's average temperature was −24 °C thought that it was more important to limit climate change than those who were told that it was −16 °C. However, participants who were told that the average temperature was −11 °F thought it was *less* important to reduce the carbon footprint than those who were told that it was 3 °F. The findings contradict each other since −24 °C is the same as −11 °F, and −16 °C is the same as 3 °F. We draw on research on numerosity and goal-pursuit from behavioral psychology to explain the intriguingly-opposite findings. We measure both the perceived influence of and actual behavior to help fight climate change. Thus, we offer the novel hypothesis that presenting climate change figures in Celsius or Fahrenheit—two primary units to communicate temperature—can influence people's belief in or concern regarding climate change.

1. Introduction

Climate change refers to the gradual change in the Earth's climate and physical geography that accompany an increase in the Earth's temperature. It is one of the greatest challenges facing life on Earth (Karl, Melillo, & Peterson, 2009; National Research Council, 2011; Solomon, Plattner, Knutti, & Friedlingstein, 2009). Therefore, it is important to limit—if not stop entirely—human activities that contribute to temperature change.

In this research, we focus on how climate change information is communicated how it might influence individuals' response and behaviors to reduce climate change. The literature on scientific communication is vast. For example, presenting "plain facts, pie charts, or metaphors" can shape people's belief in the existence of climate change (Van der Linden, Leiserowitz, Feinberg, & Maibach, 2014). Also, framing climate change information in various ways can "override" people's deeply-held beliefs about the existence of climate change (Aklin & Urpelainen, 2014; Ding, Maibach, Zhao, Roser-Renouf, & Leiserowitz, 2011; Kahan, Jenkins-Smith, & Braman, 2011; McCright, Dunlap, & Xiao, 2013). Similarly, framing a message in terms of losses or gains can shift the perceived influence of a rise in the Earth's temperature (Kahneman & Tversky, 1979; Nisbet, 2009; Spence & Pidgeon, 2010).

This research presents another way to frame climate change information and change its perceived impact. The two most common ways of presenting temperature information is either in Celsius or Farenheit units. Farenheit is used in the United States, the Bahamas, Liberia, and other select countries. Celsius is more common in most parts of the world. We predict that people who are told that the average temperature is, say, −24 °C will think that it is more important to prevent climate change than those who are told that it is −16 °C as warmer temperature should have larger and more devastating effects in colder countries, consistent with tenets of diminishing sensitivity (Tversky & Kahneman, 1991). But it is also posited that people told that the average temperature is −11 °F will think that it is *less* important to do so than those who are told that it is 3 °F. These two predictions seemingly contrast each other, since −24 °C is the same as −11 °F, and −16 °C is the same as 3 °F. As such, people's larger response to −24 °C than to −11 °F goes against rational predictions. To advance such a prediction, we draw on numerosity and goal-pursuit in behavioral psychology.

How scientific information regarding climate change is communicated is important in shaping concerns about this grave issue facing the planet and its citizens. But, although Celsius and Fahrenheit are the two basic ways of presenting temperature information, an understanding of their likely impact in climate change information communication is absent. While Fahrenheit is only used in select nations around the world, our finding, as counter-intuitive as they may be, might explain why some countries and their peoples continue to believe climate change is less of a concern—or not a concern at all.

2. Theoretical framework

Wee draw on two streams of literature to make our prediction that attitudinal and behavioral responses to climate change information presented in Celsius and Fahrenheit might differ. The first is

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https://doi.org/10.1016/j.jenvp.2018.09.002
Received 14 June 2018; Received in revised form 20 September 2018; Accepted 30 September 2018
Available online 03 October 2018

numerosity. Numerosity research posits that numeral units impact judgments due to the size of the associated number, and that people tend to disregard the base unit. A well-known example is the "money illusion", where people anchor on the nominal value of a foreign currency and adjust it for the exchange rate (Pelham, Sumarta, & Myaskovsky, 1994; Raghubir & Srivastava, 2002; Shafir, Diamond, & Tversky, 1997). But because this conversion is difficult to make, the adjustment is inadequate, causing a biased evaluation towards the nominal value of the foreign price. Thus, people consider $16 Hong Kong Dollars to be "more expensive" than $2 U.S. Dollars because "16" is larger than "2", even though $16 HKD and $2 USD are equal when considering exchange rates. Similarly, in judgments about time, one year can be represented as 365 days, 52 weeks, or 12 months. Presenting time information as 12 months would increase how "long" people feel the duration is, compared to "1 year" since "12" is larger and thus feels longer than "1" (Chandran & Menon, 2004; Zhang & Schwarz, 2012).

Interestingly, one area in which numerosity effects have *not* been studied is in temperature judgments. Despite differences in popularity depending on country and region, temperature information can be presented in either Celsius or Fahrenheit. One key difference between temperature units and other units such as money and time lies in the reference point. Consider money judgments, $0 USD is $0 CAD, which is $0 AUD and €0 and £0. Similarly, in time, 0 months is the same as 0 years and as 0 days.

But in temperature, the reference point differs. In Celsius, the most obvious "anchor" from which people could make temperature evaluations is 0° C—or the point at which water freezes. Values above indicate warm temperatures and values below indicate cold temperatures. But in Fahrenheit, there are two possible anchors. One might be 32 °F, the point at which water freezes. Individuals who are familiar with Fahrenheit especially would recognize that 32 °F is the point at which water freezes, making it a likely reference point. But there is also another possible reference point, 0 °F. It is semantically meaningless. As it is equivalent to −18 °F, it is impossible to determine, relatively, if 0 °F is "cold" or "hot," unlike 32 °F at which it is a useful anchor since water freezes at this point, making it possible to determine whether the temperature is freezing or hot. Yet 0 °F could still be useful psychologically as it is a nice round number and salient figures are often considered as reference points (Dehaene, 1992). This "two-reference point" possibility for Fahrenheit, we suggest, can have implications for how people consider or judge deviations in temperature in this particular unit.

Consider 64 °F. People familiar with Fahrenheit could conceivably assume that it is "twice as warm" as 32 °F. Scientifically, such a judgment is erroneous. Although 32 °F is the point at which water freezes, it is not a scientifically-correct reference point since 64 °F could just as easily be compared to any other temperature. Yet, since 32 °F, we suggest, might be a possible reference point, individuals might make such a conclusion about 64 °F being "twice as warm" as 32 °F. Assessing, say, 16 °F to 32 °F also makes sense, as people likely assume that it is about "half the temperature" from 32 °F. But what about −14 °F, or any temperature below 0 °F? How cold (or warm) might this be? Comparing this temperature against 32 °F is difficult, as one must not only calculate the difference between −14 °F and 0 °F, but also that between 0 °F and 32 °F. This mental addition is cumbersome and draws on cognitive resources that are limited. Thus, we posit that, with temperatures below 0 °F, a more natural reference point might be 0 °F. Meanwhile, temperatures above 0 °F are likely anchored at 32 °F since it is more meaningful—at least psychologically—to evaluate. 16 °F is easy to compare to 32 °F, but not to 0 °F. One would likely find it hard to describe 16 °F as "colder than 0 °F" since 0 °F does not refer to any specific temperature that is useful. The implication of these possibilities is that −14 °F might be perceived as relatively *warmer* than 3°, because −14 °F is only about 15° colder than 0 °F, but 3° is about 30° colder than 32 °F. At least, −14 °F may not feel as cold as 3 °F because judgments about how cold (or warm) need to be made against some comparison point as with other judgments such as about money or time (Kahneman & Tversky, 1979). We stress that these are "lay judgments; " doubling of Celsius or Fahrenheit, which are interval scales, does not double the temperature.

To test this "two-reference" possibility, we conducted a pilot test with 101 American participants recruited from an online panel managed by Qualtrics (mean age of 34.2 years old). They were randomly placed into the Celsius or Fahrenheit condition. In the Celsius condition, they were given four temperatures in Celsius and asked to write down the temperature in Celsius that would be "twice as cold" for temperatures below 0 °C or "twice as warm" for temperature above it. As we predicted, for the value that would be twice as cold as −20 °C, the mean was −34 °C (*S.D.* = 7.56 °C). For the value twice as cold as −10 °C, the mean was −17 °C (*S.D.* = 3.24 °C). For the value twice as warm as 10 °C, the mean was 20 °C (*S.D.* = 0.45 °C). Finally, for the value twice as warm as 20 °C, the mean was 41 °C (*S.D.* = 1.23 °C). The responses suggest a reference point at 0 °C. In the Fahrenheit condition, participants were also given four temperatures and also asked to write down the temperature that would be "twice as cold" for temperatures below 32 °F or "twice as warm" for those above. Here, for the value twice as cold as −4 °F, the mean was −10 °F (*S.D.* = 2.31 °F). For the value twice as cold as 14 °F, the mean was −11 °F (*S.D.* = 5.11 °F). For the value twice as warm as 50 °F, the mean was 92 °F (*S.D.* = 4.36 °F). And, for the value twice as warm as 68 °F, the mean was 129 °F (*S.D.* = 10.45 °F). These results imply a reference point at 0 °F for temperatures below it but one at 32° for temperatures above 0 °F.

These findings provide evidence that people's reference points differ for Celsius and Fahrenheit. So, how does this impact the communication of climate change information? Much of this information tends to use statements such as "the Earth will rise by *X*° in *Y* years", where there is a degree change in temperature within a certain timespan. Though, the aforementioned findings regarding the differing reference points depending on the temperature unit suggest that this stated rate of change and its temperature unit together influence the perceived impact of the information about the seriousness of climate change. Here, we draw on the goal-pursuit theory, in which people have a motivation to avoid an undesired end-state. According to this body of research, early changes are significant, but subsequent changes are less so (Bonezzi, Brendl, & De Angelis, 2011; Förster, Higgins, & Idson, 1998; Koo & Fishbach, 2012). That is, perceived progress towards a goal at the beginning might be more motivating than perceived progress near the end. For example, suppose that a student beginning college would like to avoid gaining the "Freshman 15" during freshman year. ("Freshman 15" is an American expression that suggests that first-year university students tend to gain 15 pounds.) The first pound that she gains would seem disastrous to her avoidance goal, but any subsequent pound gained would have a marginal, diminishing effect; it would seem less concerning.

Such a motivation to avoid an undesired end state could be applied to climate change behaviors. In particular, since the undesired end-state to avoid is a "warm" planet, a perceived increase in temperature when it is relatively cold might seem impactful and disastrous, leading one to think the end-goal is far away and perhaps even unattainable. But, a perceived increase when it is relatively warm might seem less impactful as the Earth is already "quite warm" and any further increase would have marginal impact. Yet, the consideration of reference points in Celsius and Fahrenheit is important here. In Celsius, an increase in temperature when the Earth's average temperature is, say, −24 °C, can seem more harmful of a rise than when the temperature is, say, −16 °C. This is because people perceive −24 °C to be relatively colder than −16 °C, and any increase is more impactful upon the first than the second figure. In Fahrenheit, the possibility of two-reference points leads to interesting implications. It proposes that an increase in temperature when the Earth's temperature is, say, −11 °F, would seem *less* impactful of a rise than when the average temperature is, say, 3 °F. This