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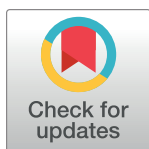
OPINION

Harnessing the mental imprints of climate change for collective climate action

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Early this year, the United Nations made an ominous announcement: *There is a rapidly closing window of opportunity to secure a livable and sustainable future for all.*

Planetary warming and extremes thus far have already impacted ~5 billion people [1, 2]. Despite such global impacts, fossil fuels—the major source of the warming—are still contributing 78.5% of global energy [3]. Without drastic actions to phase out carbon emissions within two decades, time will run out [4].

The overall goal is to bend the warming curve before 2050 and keep the warming well below 2°C [3, 4]. Yet, a major stumbling block is the lack of massive bipartisan support for drastic actions. Can the burgeoning health impacts of climate change provide the needed opening to garner support?

Human health is directly as well as indirectly impacted by the same pollution sources that are heating the planet [2, 5]. Air pollution from fossil fuels leads to as many as 10 million deaths each year [6]. In addition, over a 20-year period (1995 to 2015), weather disasters have left 4.1 billion people injured, homeless or in need of emergency assistance [7]. Worldwide, heat-related deaths have increased by 68% in the last 20 years [8]. If these are not enough reasons for concern, another major dimension of health risk is emerging, and this concerns the impacts of global warming and related weather extremes on mental health [9].

With regard to mental health, we are just starting to define and understand the dangerous implications of *climate trauma* [9, 10]. We are witnessing emerging mental health challenges such as ecological grief and eco-anxiety driven by the awareness of disastrous long-term climate damage simultaneous with delayism in global climate actions.

Our own research within communities exposed to climate change accelerated wildfires has evidenced nearly 2–3X greater prevalence of post-traumatic stress disorder (PTSD), anxiety and depression [11]. Following up with recent mechanistic research, we show that the mental health effects of climate change are not just restricted to subjective clinical symptoms, but that chronic cognitive and brain functioning impacts are also observed [10], i.e., underlying the self-reported symptoms, there are objectively measurable biological impacts. In our study, wildfire-exposed individuals, relative to controls, performed much worse when resolving distractions within a cognitive task. Alongside, their frontal executive brain regions were hyper-aroused—showing significantly greater brain activity, trying to perform the desired cognitive function with greater effort, but failing. It is especially concerning that we found this evidence in the long-term—chronic impacts on mental health and brain health were observed more than six months after the disaster. Thus, *climate trauma* is literally rewiring our brains and leaving long-term imprints. Of note, these impacts are sure to exacerbate the existing mental

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health crisis that currently has one billion people living with mental disorders at a global cost-burden of \$1 trillion [9].

Urgent climate action is the need of the hour, but as individual persons and organizations, we focus on immediate short-term benefits, and shy away from sacrifices that are needed for long-term sustainability. In one of our other recent studies of how humans process rewards [12], we gave people the choice of two decks. One deck led to frequent short-term small value

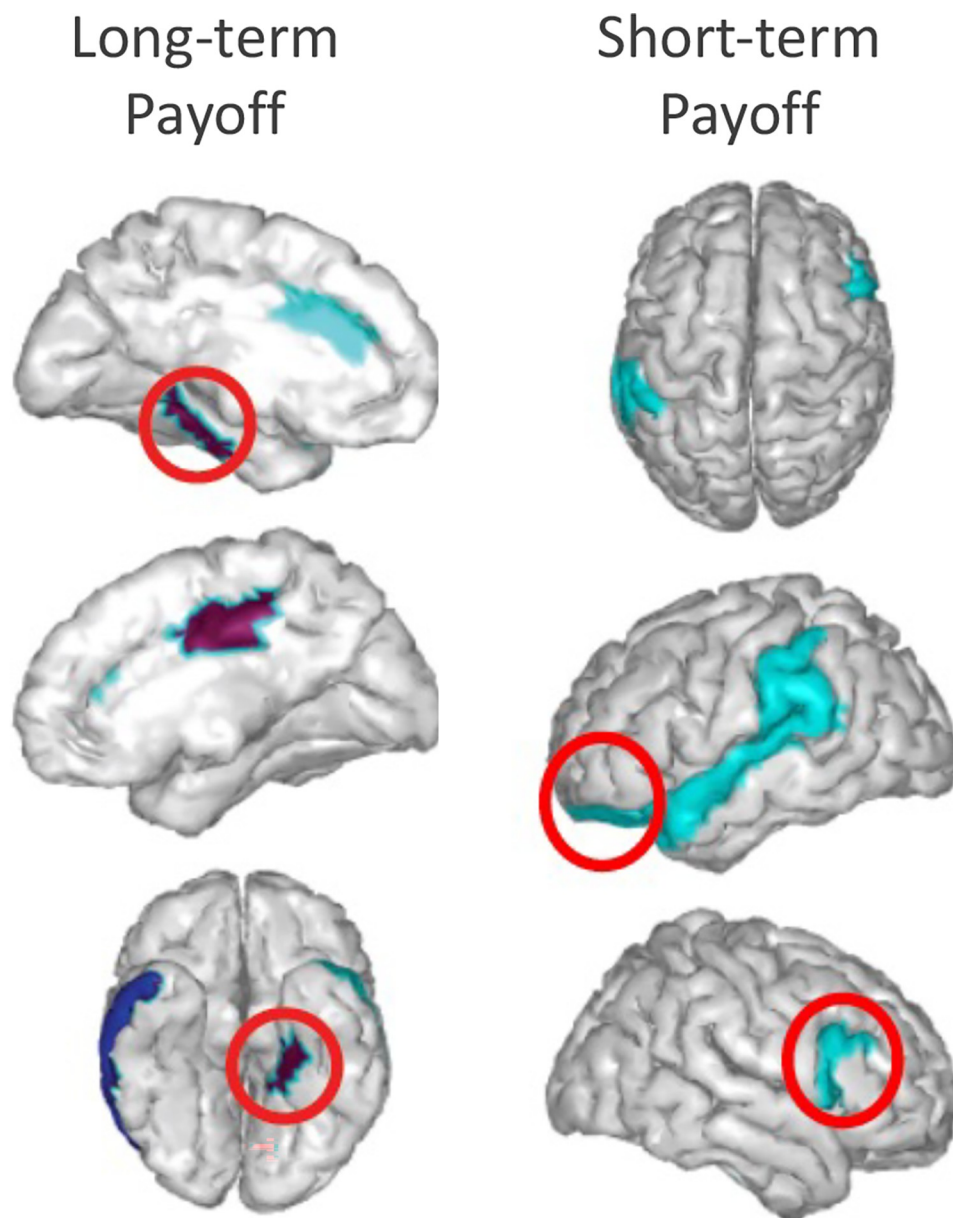


Fig 1. Brain activity correlates of human performance when choosing long-term payoff show medial brain region activations, especially in memory processing areas (encircled in left column). In contrast, human performance when choosing short-term payoff relates to activity in frontal brain regions, especially regions involved in immediate reward processing (encircled in right column). Non-encircled colored brain activity is significant on the payoff task but doesn't directly correlate with performance. Different colors denote different oscillatory frequencies of brain signals; dark blue: 3–7 Hz theta band, brown: 8–12 Hz alpha band, cyan: 13–30 Hz beta band [12].

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rewards, yet rare but large long-term losses, which cumulated to net loss. The second deck led to frequent small value losses, yet rare but large long-term gains, which cumulated to net positive benefit. The first deck is equivalent to the state of the capitalist society today focused on short-term profit, while the second deck is more aligned with a sustainable future. We found that sans any other prior knowledge, people across the human lifespan, from teenagers to older adults, chose these decks in near equal proportions. Yet, when we analyzed the underlying brain activity, we found that choosing the long-term payoff deck recruits parts of the brain involved in memory processing, which are distinct from parts of the brain involved in assigning immediate reward value (Fig 1). Why is this important for how we plan for the future of planetary health?

It is telling us that our long-term memory systems get activated when we take in short-term losses to cumulate long-term benefits. Short-term losses are equivalent, for instance, to divestment from fossil fuels as we build a long-term green energy future. That our memory systems are active when we assimilate long-term rewards is significant because memory imprints have been evidenced to guide future adaptive [13]. Furthermore, presence of eco-anxiety can serve to persuade political change [14]. So if enough of us have such mental imprints, would it cross the threshold for collective environmental action?

Time is running out for transforming society to collectively shift perspective to the long-term. Societal transformation will require a fundamental shift in how we view and internalize the health impacts of climate trauma on ourselves, our children, grandchildren, and generations to be born. In this context, our mental imprints must motivate us to mount large-scale, collaborative and interdisciplinary efforts to continue to understand, build awareness and take action against the grave health risks we face from climate change, especially within frontline communities.

Urgently required is a new people-centered research agenda that factors in the debilitating mental health risks of climate change. The new trans-disciplinary research should not only evaluate climate risks but also create policies and solutions that can help people cope with the unavoidable risks. We need collective action and also customized action tailored to community needs. Encouraging evidence already suggests that framing climate policy in the context of health can bolster public support, even amongst those unconcerned [15].

All current living generations have the memory stamps of spending summers in nature without bothering about wildfire danger or heat stress. The serene climate and natural environment rejuvenate us. But when nature is under attack, it can chronically traumatize us and threaten our mental well-being. It is essential that we harness our prescient mental imprints to target the long-term payoff of climate-neutral planetary health and well-being.

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