Beyond Threshold Approaches to Extreme Heat: Repositioning Adaptation as Everyday Practice

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ABSTRACT

One of climate change's most certain impacts is increasingly frequent and extreme heat. Heat management and climate adaptation policies generally utilize temperature and humidity thresholds to identify what constitute ''extreme'' conditions. In the workplace, such thresholds can be used to trigger reductions in work intensity and/or duration. In regions that routinely exceed proposed thresholds, however, this approach can be deeply problematic and raises critical questions about how frequently exposed populations *already* manage and mitigate the effects of extreme heat. Drawing on social practice theories, this paper repositions everyday engagements with extreme heat in terms of practices of work. It finds that bodies absorb and produce heat through practices, challenging the view that extreme heat is an ''external'' risk to which bodies are ''exposed''. This theoretical starting point also challenges the utility of threshold-based adaptation strategies by demonstrating how heat is actively coproduced by living, performing bodies in weather. This argument is exemplified through a case study of outdoor, manual workers in Australia's monsoon tropics, where work practices were adapted to reduce thermal load. More specifically, we find that workers ''weather'' work and ''work'' the weather to enable work to be done in extreme conditions. Our analysis of everyday heat adaptation draws attention to the generative capacities of bodies and unsettles two established separations: 1) that between climatic exposure and sensitivity, calling for a more embodied, experiential, and performed perspective and 2) that between climatic impacts and (mal)adaptation, calling for an understanding of climate adaptation, as located in everyday practices, in the management of bodies in weather.

1. Introduction

Extreme heat and heat waves are some of the most far-reaching impacts of climate change in terms of geographical spread, human health, and economic costs (World Bank 2012; McMichael and Dear 2010; Kjellstrom et al. 2009). In accounting for heat-related impacts of climate change, threshold-based approaches offer one mode of calculating impacts on morbidity, mortality, and productivity. At the everyday scale, threshold-based heat management and adaptation policies are also used to set environmental limits that trigger risk mitigating responses, such as reducing people's exposure to heat by placing them in (artificially) cooler conditions (Hitchings 2011). Implicit in these approaches is a problematic assumption that exposure to environmental conditions is the prime determinant of heat risk. Here, we challenge this perspective, particularly for outdoor workers, by repositioning the focus from (workers') exposure to heat to *how* heat and heat stress emerge through social practices (of work). In making this novel intervention, the paper proffers a theoretically grounded empirical approach through which we can begin to address calls, such as that by Kjellstrom et al. (2016, p. 97), for ''more analysis of climate change–related occupational health impact assessments.''

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There are at least three bodies of literature that challenge the environmentally deterministic understandings of climate change vulnerability evident in threshold-based approaches. First are those originating in critical social science that are attentive to questions of political economy and underline the importance of contextual, social factors (O'Brien et al. 2007; Leichenko and O'Brien 2008; Eisenman et al. 2016). Such work examines the complex social or ''syndemic'' vulnerabilities that emerge at the intersection of unevenly distributed threats at multiple scales, making clear that climatic factors are not the only stressors a group faces (e.g., Willen et al. 2017). While important, this literature gives little attention to *bodily* experiences or activities, nor does it distinguish populations on the basis of the *practices* with which they engage, as opposed to their characteristics of location, class, or ethnicity.

Physical effects and differences are addressed by a second body of literature on the climate–health interface. Some of this discusses humans as a single group whose biology imposes an adaptation limit [e.g., >35°C as discussed by Sherwood and Huber (2010)]. More nuanced is work that highlights that some bodies are more sensitive and less adaptive to particular climatic stressors than others (e.g., Kovats and Hajat 2008; Zivin and Shrader 2016). While valuable, this literature still tends to essentialize bodily differences and imply that besides certain ''exceptional'' groups (such as infants and the elderly), bodies in general are relatively standard and stable. This notion of humans as collections of uniform bodies occludes the fact that bodies are not just unique, but dynamic sites of constant energetic-material change (Oppermann and Walker 2018) from which heat can emerge as an ''impact'' depending on bodily particularities and practices.

Third, a more interpretive literature emphasizes the subjective and cultural character of climate, weather, and associated disasters. This includes different meanings given to climatic or weather conditions (Hulme 2016), the risk they are perceived to entail (e.g., Frondel et al. 2017; Boronyak-Vasco and Jacobs 2016), or the perceived intensities and types of harm and loss different groups experience following extreme weather events (e.g., Barnett et al. 2016; Adger and Barnett 2009). The growing appreciation that we do not all interpret climate and weather the same way further unsettles the value of universal numeric thresholds in designating dangerous environmental conditions. Nevertheless, a purely interpretive approach can underplay the material realities of heat and the generative role of bodily activity in shaping heat.

Absent in all three literatures is the role of everyday, embodied experience, which we examine below through social practice theory. In contrast to using objective environmental thresholds to determine behavior, practices reframe the object of social enquiry as shared ways of performing routine tasks. Practices are routinized activities shaped by the articulation of available elements of meanings, competences, and materials (Shove et al. 2012), which entails an intimate and coproductive relationship of bodies and environment, including with heat (Oppermann and Brearley 2018; Oppermann and Walker 2018; de Vet 2017). How practices are performed, we argue, shapes the extent to which heat is generated, absorbed, or lost at the bodily level, as well as how it is experienced, noticed, and attended to.

This paper explores the practices of heat-exposed outdoor workers in northern Australia's monsoon tropics: a hot region in a hot continent, getting hotter. Many Australian organizations and government departments use environmental thresholds of temperature, or temperature indexed with humidity, to identify and manage extreme heat. Yet, large regions of the country, notably the tropical monsoon zone, already routinely exceed recommended environmental thresholds (Oppermann et al. 2017). For up to 6 months of the year, the tropical monsoon zone is subject to medium–high temperatures in conjunction with extremely high humidity. In combination, these conditions are known to have particularly negative impacts on human health in the form of heat stress (Kovats and Hajat 2008; Hanna and Spickett 2011). For people working outdoors, conditions are highly likely to exceed at least some of the recommended environmental thresholds for much of this period (Jia et al. 2016) and substantial slowing or even cessation of work is often recommended (Oppermann et al. 2017).

In reality, however, work continues despite conditions exceeding these thresholds (Jia et al. 2016; Brearley et al. 2015), raising critical questions about *how* exposed populations *already* manage the effects of extreme heat. This question has been explored in relation to everyday domestic practices in Australia's monsoon tropics by de Vet (2017). Theories of social practice are also an emergent area of theoretical innovation in accounting for how everyday life adapts to global environmental change (Feola 2015). Only a handful of social practice studies have explicitly explored responses to climate change. These have generally been in relation to mitigation and sustainable consumption (Shove et al. 2012; Shove and Spurling 2013; Spaargaren 2011; Spaargaren et al. 2016) or broadening resilience to energy and water shortages by improving householders' adaptive capacity (Strengers and Maller 2012).

Here, we employ social practice theory to reframe the question of how outdoor workers currently deal with extreme environmental heat in Australia's monsoon tropics and identify implications for how adaptation to climate change is theorized. We draw on a pilot study conducted in Australia's monsoon tropics to demonstrate how weather conditions coproduce outdoor working practices, and that working practices can manufacture or mitigate bodily heat and heat stress, normalizing and/or seeking to actively prevent or otherwise manage it. As such, we argue that the heat that matters is not determined by environmental thresholds nor is it successfully managed by approaches based on them. Rather, heat is coproduced by bodies and environments such that weather and climate matter differently in relation to what bodies *do* as a result of the practices they are engaged in.

We begin by discussing current climate change adaptation strategies in Australian workplaces and how these rely on specific environmental ''heat'' thresholds (section 2). To account for *how* work continues in conditions that exceed these thresholds, we use theories of social practice to posit an alternative account of adaptation to current and projected climate change (section 3). We demonstrate this theoretical repositioning through the example of a power network maintenance crew in Darwin, a city in Australia's monsoon tropics (section 4). Our analysis challenges the view that heat and humidity are an ''external'' risk to humans and instead reframes climate change impacts and adaptation in terms of embodied experiences and social practices (section 5). We conclude by articulating what this understanding means for climate change adaptation policy and strategies.

2. Heat thresholds and climate change in Australia's monsoon tropics

More people are killed by extreme heat in Australia than by all other natural hazards combined (Coates et al. 2014) and climate change projections show temperatures rising substantially, further increasing heat-related morbidity and mortality (Bi et al. 2011; McMichael et al. 2003, 2006). A number of adaptation strategies have been proposed (Bambrick et al. 2008; Hanna and Spickett 2011; Singh et al. 2015), many of which rest on identifying critical environmental thresholds at which public health and occupational health responses are triggered. Historically, days with a maximum of over 35° or 40°C have been understood as significant for human health (Hughes et al. 2016), and Australian climate change projections reports have typically identified the number of days likely to exceed these thresholds as a key measure of impacts (Green 2006; Moise et al. 2015; Hennessy et al. 2004). More recently, Australia's Bureau of Meteorology began providing observations of extreme heat categorized in terms of ''excess heat factor,'' which identifies the severity with which temperatures exceed a threshold based on a location's recent climate history (Scalley et al. 2015).

In occupational settings, extreme heat is understood to be dangerous as a result of exposure to, and exertion in, these conditions (Gubernot et al. 2014). Propelled by heat-related occupational deaths in key sectors, a number of Australian organizations, academic commentators, and a coroner (Briggs 2016; CFMEU 2016) have called for official environmental thresholds at which work should be reduced or ceased. The apparent clarity of threshold-based approaches is assumed to be a reliable way of preventing heat-related illness and has occupied a central place in the national discourse of how to manage extreme heat. Within this discourse, there has been contestation over the exact threshold at which workers should ''down tools'' (Watson 2016) and whether there should be regional differentiation in workplace thresholds—including through adjusting the threshold for acclimatized and nonacclimatized personnel (Hanna and Tait 2015; Oppermann et al. 2017). Debate has extended beyond the ''value'' at which a threshold is set within a metric (most often simply ambient temperature) to *which* metric should be used. Physiologically, this is because humidity and other factors, such as air velocity and radiation, play a significant role in body heat balance (d'Ambrosio Alfano et al. 2011). There are many indices that take such factors into account, such as the wet-bulb globe temperature (WBGT) or universal thermal climate index (Blazejczyk et al. 2012; Miller and Bates 2007; d'Ambrosio Alfano et al. 2014). Which metric is used can be highly significant for when work is reduced/stopped in a particular location. For example, the Construction, Forestry, Mining and Energy Union (CFMEU) contends that a 35°C temperature threshold can underrepresent heat stress risk in humid conditions, suggesting 28°C with 75% humidity should be seen as an equivalent threshold (CFMEU 2016).

Third, in addition to variation in the level of the threshold and choice of index, views about what actions threshold attainment should stimulate also vary. In general, thresholds are meant to act as an external environmental trigger for behavioral change to mitigate the risk posed to human health from heat. However, environmental conditions are only one source of heat stress. Heat stress, heat-related illness, and, in more extreme cases, heat stroke are the result of the body's accumulation of heat (Brearley et al. 2015; Lee et al. 2016). This is caused not only by the absorption of exogenous heat from the weather, but by radiant heat from the working environment, such as asphalt and metal surfaces. The body's thermal load is also shaped by endogenous heat production through metabolic processes secondary to exertion. Furthermore, hydration levels, which are related to the body's thermoregulation system (which sweats to cool off; Jay and Brotherhood 2016), and the ability to rest (lower exertion) or actively cool the body to allow heat to dissipate are all key aspects of ensuring safe thermal load (Brearley 2016). The multiple causes of heat production, absorption, and retention/loss in the body means that basing heat-management strategies on environmental thresholds alone can misrepresent (including overplaying and downplaying) the thermal threat.

Threshold protocols also have social effects that can sometimes run contrary to their workforce protection objectives. In their observation of a simple ''stop work'' threshold protocol in Adelaide, South Australia, Lao et al. (2016) examined how weather forecasts enabled managers to anticipate that an environmental threshold would be reached at a certain time on a certain day, with some consequentially *increasing* their team's rate of work to complete a job prior to the anticipated shutdown order. As a result, workers became *hotter* than they might have done if they had continued the job at a normal rate, or self-paced in response to rising temperatures. Although not used in Lao et al.'s case study, many threshold approaches resolve this issue to some extent through staged workload reduction at different temperature increments (see, e.g., Miller and Bates 2007). While the latter approaches recognize exertion and heat loss through rest in addition to exposure, they still privilege environmental conditions as the determining factor of work rate, occluding other material and social factors.

Regardless of the metric used, in climatic regions that routinely exceed proposed limits, even staged approaches to thresholds have proven difficult to implement in occupational settings because the perceived impost on productivity is so significant. Northern Australia's tropical monsoon zone is one such region (Moise et al. 2015; Peel et al. 2007), with relatively high temperatures combined with very high humidity for up to seven months of the year. There are no formally instituted thresholds at state or national level for the region (Hughes et al. 2016), although there are some protocols recommended by unions or instituted at the organizational level. Such protocols vary widely depending on the particular metric or protocol used, yet instituting mainstream thresholds for work-to-rest ratios would slow or reduce work from 50 to 0 min of every hour for up to 6 months of the year (see, e.g., Miller and Bates 2007; Parsons 2006; Jia et al. 2016; CFMEU 2016).

Although such measures are intended to protect workers, the potential for such extensive impacts on work time and rate means it is perhaps unsurprising that official or recommended thresholds and responses are largely ignored in practice. In a 2015 study of a construction firm in Darwin, Jia et al. (2016) explored why a construction union's policy was *not* implemented on site. At the time of the study, this policy proposed a staged increase in rest periods from ambient temperatures of 30°C and higher. Utilizing observed weather data, they estimated a 24.7% productivity loss if the policy had been followed. The fact that workers managed to continue working without these breaks raises the question of whether the threshold is set at the ''right'' level from a physiological and economic, if not worker safety or rights, point of view. Furthermore, given that it was reasonably hot, it also raises the questions of what exactly enabled workers to continue working? In other words, *how* might exposed populations *already* be adapting to extreme heat in the region?

3. Reframing environmental change through theories of social practice

To understand how heat stress eventuates and is managed on a daily basis in extreme conditions, we now turn to theories of social practice. These theories are situated in a broader sociological history of the ''everyday'' (e.g., De Certeau 1984), which has sought to reposition the object of social enquiry onto everyday practices and their rhythms, variations, and temporalities. While there are different interpretations, a ''central core'' of practice theorists ''conceives of practices as embodied, materially mediated arrays of human activity centrally organized around shared practical understanding'' (Schatzki 2001, p. 11). Moreover, a ''posthumanist'' subset contends that practices include nonhumans such as machines and objects as ''participants'' (Reckwitz 2002b), which can perform or coperform everyday practices in collaboration with humans (Shove et al. 2012; Reckwitz 2002a; Maller and Strengers 2018). Practice theories also foreground the adaptability of bodies, including the skills and knowledge that they carry, which provides insight into the lived experience of weather and adaptation to changing conditions (Maller and Strengers 2013, 2015; Maller 2018).

Social practices can be understood as ''what make sense'' for people to do as they engage in everyday activities (Schatzki 2010). Shove et al. (2012) develop an analytics of practices as routinized performances as emerging from three kinds of elements: *meanings*, which are ideas or understandings about how and why to carry out the practice; the *materials*, including tools, with which they interact and utilize to perform the practice; and the learned and embodied *competences* or skills available. Availability is important as practices are patterns ''which can be filled out by a multitude of single and often unique actions'' (Reckwitz 2002b, p. 250); hence, different elements can be combined each time a practice is performed (Hui 2017). Populations are defined by those who perform the practice and draw on available and shared elements—of meanings, materials, and competences—to make sense of how to act. The practitioners of outdoor power network maintenance practices not only perform such practices, but have the capacity to innovate and adapt these practices in response to changes in the availability and desirability of particular elements. Because of this internal variation, practices are sites of ongoing reproduction and change (Hui 2017).

In this paper we follow practice-theory scholars who conceptualize bodies as ''handling'' weather and heat by responding not only physiologically but also by utilizing appropriate meanings, competences, and materials (Maller and Strengers 2015; Reckwitz 2002b; Oppermann et al. 2015; Oppermann and Walker 2018). As Wallenborn and Wilhite (2014, p. 57) explain, bodies are ''at the intersection of the cultural and natural, the human and non-human, the individual and collective.'' Adaptation to contemporary climate change, experienced as weather conditions in everyday life, can be viewed as the variation of practice in relation to changing availability and utility of practice elements. Weather is positioned here as one of multiple *materialities* that bodies experience (as temperature, humidity, wind), some of which also may be coproduced (hot surfaces, wet skin; Oppermann and Walker 2018; Strengers and Maller 2017). Practitioners of outdoor work know and interpret these materialities through somatic and sensory means (such as feeling hot, sweaty, or nauseous) and interpret these experiences in particular ways, such as ''normal,'' ''tolerable,'' or ''extreme''). However, how hot it is felt to be is also a product of what the body is doing to handle the weather through embodied *competences*. These may be physiological (such as the body adapting to sweat more profusely), or may draw on learned and embodied knowledge (such as slowing their pace in higher temperatures). As such, abstract and universalized meteorological measures and thresholds are only rendered *meaningful* in relation to the body and the practices in which it is participating. Furthermore, climate change can be ''known'' by how it ''feels'' in everyday life and through what is ''done'' in relation to it. More fundamentally, weather and climate change are in this way coproduced by practices.

Grounded in this theoretical approach, the actual ''thresholds'' at which heat stress occurs can be understood as an effect of varied and temporally unfolding practices. In extreme and changing conditions, these dynamics constantly (re)position the boundary of what constitutes heat stress, whether it occurs, and its severity. As such, social practice theories go beyond considering physiological adaptation in conjunction with social adaptation (Hanna and Tait 2015), instead demonstrating how these are actively coproduced. Adaptation is thus the capacity to manage these constituent relations in such a way that the practices of which they are part—such as work—are able to continue. We elaborate on this framing below through our study of outdoor work in Australia's monsoon tropics.

4. Study: A power network maintenance crew in Australia's monsoon tropics

a. Methods

This research was part of a pilot study on the social practices of a chronically exposed power network crew in Darwin in early 2015. The study was conducted by the first and last authors, with the objective of developing a transdisciplinary physiological and ethnographic approach to heat stress research, developed through critical engagement with social practice theory. The first author was responsible for observing a 3-h outdoor maintenance task toward the end of the hot and humid wet season. Recorded interviews of 20–30 min were conducted with six active crew members immediately following task completion. Three follow-up interviews of 30–60 min were conducted with middle and senior management over the following two weeks.

This paper utilizes interview data from the study, using pseudonyms to protect participants' identities. The interviews explored how heat stress was experienced and managed during the observed task, and what practices contributed to or modified body heat production and associated heat stress symptoms in the practice of repair work more broadly. The three managers interviewed had directly shaped how the observed task was undertaken through practices of managing logistics, site safety, and allocation of workers. They were asked about how these practices affected and responded to heat and other aspects of work practice on site. All interviews were transcribed and coded in NVivo using 1) Shove et al.'s (2012) social practice elements of materials competences, and meanings together with 2) activities related to exposure, exertion, cooling, hydration, and food consumption and 3) indicators of contingent relations and temporal effects on thermal load and heat stress symptoms, such as sequencing, frequency and duration of exertion, and exposure. From this, our analysis explores the different ways in which working practices produce and manage heat in bodies over time, coproduced by particular combinations of practice elements and variations in practice.

b. *The materiality of ''heat'' in the monsoon tropics*

Australia's monsoon tropics have a notoriously hot and humid climate. British colonial accounts of the region's climate negatively affecting people's physical and mental health persist in the popular use of the phrase ''going troppo'' in the region (Lobo 2013; Rickards and Oppermann 2018). More recently, the term ''mango madness'' (Cloonan 1998) has emerged, describing shortened tempers and erratic behavior during the particularly hot and humid weather that occurs at the same time as the regional mango harvest. Such colorful phrases are indicative of the meanings and materialities of heat stress, which infuse social practices in the region (de Vet 2017; Oppermann et al. 2017).

These local phrases also indicate an experiential way of knowing and managing (or failing to manage) heat, physically and psychologically. Human physiology explores heat stress in terms of heat balance through thermoregulation, the process of responding to environmental conditions to maintain stable internal temperature. The gradient between ambient and skin temperature determines the potential for body heat dissipation through radiation and convection. High ambient temperatures limit the ability of the body to cool itself through measures such as the evaporation of sweat (Galloway and Maughan 1997). Moreover, when ambient humidity as well as temperature is high, sweat is unable to evaporate because the air is already saturated with water vapor (Berglund and Gonzalez 1977). In this way, the materialities of the embodied experience of monsoonal weather—the vapor pressure in the air, its warmth, and the particular physical ways in which the body tries to lose excess heat—work antagonistically, making bodies hotter. More broadly, this underlines how bodies and environmental conditions coconstitute the materiality of heat and heat stress—the heat that is accumulated or lost by the body—and how bodies ''feel'' as a result (including not only sensing being hot, but feeling irritable, or ''troppo'').

One way of understanding this coproductive materiality of heat is to consider two different metrics for ''hot'' conditions. For example, in Darwin, maximum temperatures in the wet season (including the buildup) typically range between 30° and 35°C, with minimum temperatures of approximately 26°–28°C (Goldie et al. 2015). While these temperatures may be classified as ''hot'' in their own right, they are combined with high humidity, of approximately 60% during maximum daily temperatures and 80%–90% during minimum temperatures (Oppermann et al. 2017). The relationship between the materiality of environmental conditions and the body can be represented in various ways in terms of how conditions are expected to feel. ''Feels like'' temperature, also known as ''apparent temperature'' and WBGT, among other indices, attempt to express the additional heat felt as a result of high humidity. However, human bodies and weather conditions are not the only relevant materials in how heat emerges in practice. The presence and absence of other materials, such as clothing, equipment, and tools and their radiative or conductive properties, as well as other energies such as electricity, all shape how heat is produced and managed. We now consider the material elements of work practices and heat in more detail.

c. *Placing environment, exposure, and exertion within the practice of power network repair*

Rather than focusing on weather conditions alone, one of the ways in which heat stress is produced, avoided, or managed is through what bodies are doing to ''weather the weather,'' as Vannini et al. (2012) phrase it. In heat stress physiology, this contingent relationship with the environment is accounted for as exposure to exogenous, environmental heat, and exertion as the production of endogenous heat. At issue is the body's net thermal load, which denotes that the ability to dissipate heat is crucial. Heat loss can be enabled either by lowering exertion (reducing endogenous heat production and thereby thermal load) or actively cooling the body (Brearley 2016). From the perspective of practitioners of outdoor work, the question is, how do practices of work expose them to environmental heat or cause them to produce (or lose) endogenous heat?

Interviewees' accounts of becoming hot at work demonstrated that it is how weather conditions combine with the materialities of the repair work that mediates workers' bodily exposure to heat. In reference to aerial repair work, either wearing harnesses or using a ''bucket'' (a mechanically elevated work platform attached to a truck), workers made observations such as the following:

> There was a cool breeze all day [today]. . . you get more breeze when you're in the air than on the ground. (George)

> Because the bucket's enclosed it gets warm because there's no ventilation [. . .] If your legs are out of the bucket [in a harness], you're usually a bit cooler because you're getting air across them, but it's really pretty much the same. Because [in the harness] you're just standing on hot steel then as well, which is going to radiate through your feet. (Zac)

In these instances, the accumulation/loss of heat is an outcome of *when* the job was being done (a breezy day), *where* (in the air or on the ground), and *with what* it was being done (in a harness or in a bucket). Environmental heat is thus a material element of the practice of power network repair, but the role it plays in producing heat stress is coproduced by the materiality of the fault—the location, equipment, and timing (including time of day and rate or pace) of the work required [for a physiological account of this, see Brearley et al. (2015) and Meade et al. (2015)]. It is the practice of power network repair that brings these material elements together in particular ways: the weather *with* the equipment *with* the fault *and* the bodies of practitioners. Such practices are also inherently dynamic, as the particular elements may change in each performance (Reckwitz 2002b; Hui 2017): in the case of the practice of repair work, the nature of the fault, the equipment and exertion it requires, its location, or the weather conditions will always differ.

In combination with materialities, exposure is also shaped by competences and meanings in relation to both the repair and managing the heat. One example of this emerged in relation to the somatic experience of working in personal protective equipment (PPE) clothing. As one interviewee (Bill) noted, ‘‘With older PPE that have been [. . .] worn and washed a lot, they breathe a lot more and they're a lot thinner, so the heat in [them] is less.''

Wearing old, worn PPE is not company policy and quite possibly reduces the intended protective effect of the material against abrasion and burns, but some workers wear it because it is cooler. This embodied experience is connected to the knowledge that air and sweat pass more readily through thinner fabric. Here we see that even with constrained ability to change this particular material element of repair practice, due to regulation, clothing use is still responsive to experiences of heat stress and expected exposure to hot and humid conditions. In this way, practices of outdoor work, including the element of the clothing worn for work, also actively coproduce the weather in the sense of producing how hot it feels.

Exposure is only one aspect of the imbrication of bodies and the environment through practices of work. Exertion (and its opposite, rest) are also shaped by the practice performances of work:

> [Sometimes] people want to come down [from the bucket of a lift truck] but [. . .] the job's too big and there's not enough guys. In that case, people want to swap, but the people on the ground are just as [exhausted] as the guys up the top. (Bill)

Exertion here is produced by how the nature of the fault and the number of people assigned to repair it interact with the time allotted for repair and the environmental conditions. Variations in elements of power network repair practice mean that any particular performance will produce varying degrees of exertion and opportunities for rest or slower rates of activity. As Oppermann and Walker (2018, p. 137) have argued, the ‘‘temporal patterning'' of body heat here is ‘‘intimately related to the rhythms of ‘doing' repairs and vice versa.''

The argument that body heat (and heat stress) is produced through practices of work is an important contribution to the literature on adaptation in two ways. First, it avoids the temporal and artificial disconnect between cooling and heating that exists in adaptation strategies such as the work-to-rest ratio, instead shifting the focus from when/if work is done to *how* work is done. Second, it adds important nuance to simplistic understandings of the causes of endogenous heat as simply "work rate." Drawing this simple physiological account of heat into a more complex account of materials used and thermal load over time, and embedding these in the social practices that shape *why* these materials are in play and why exertion levels occur as they do, provides a far more sophisticated understanding of how problematic levels of heat emerge as well as insights into how heat stress can be prevented and managed. How exposure, exertion, and environmental conditions are brought together becomes more open to analysis, including for the development of workplace management of extreme conditions and, more broadly, climate adaptation tactics and strategies.

d. *The temporal dynamics of heat in social practices*

Each performance of power network repair entails accumulations and losses of body heat as well as changes in hydration levels. In the study, durations of work, the pace and volume of work completed, and the sequencing or change of exposure or exertion all shaped how hot workers became. There was a clear temporal dynamic between continuity of work and the frequency of hydration and cooling, which was mediated by the materialities and meanings of the repair, its location, and environmental conditions. For example, the physical restrictions of working at heights combine with cultural norms of ‘‘not bothering other people'' or ‘‘being self-sufficient'' as well as, of course, being ‘‘efficient at work,'' exemplified here in relation to how hydration is temporally figured into work practices:

> [Being on the ground means] it can be easier to get to your water. You don't have to yell out to the person on the ground [to refill and throw the bottle up] or come down and grab it when it's empty. [. . .] If you're busy doing something, you run out of water, you're probably going to finish doing it if you're in the air and then come down (George; also reported in Oppermann and Walker 2018).

While these may appear to be insignificant decisions, they accumulate to affect hydration status and play a role in the emergence of heat stress and, ultimately, the physical capacity to work effectively (Oppermann and Walker 2018).

The temporality of work was also coproduced by the meanings of work in general, and of particular repairs. For example, planned maintenance often required scheduled power shutdowns. Dates and times were prearranged as the company had an obligation to inform customers of the outages. This created pressure on managers and crew to correctly assess repair time and then complete the repair within the established time window, regardless of weather conditions. These temporalities were also shaped by the attempt to synchronize repairs with the everyday practices of electricity consumers. For example, in a residential area, this means completing shutdown work between 0900 and 1500 local time to enable pre- and postwork/school power uses for cooking, cooling, and bathing. The result was that planned residential maintenance was typically done in the hottest part of the day, resulting in increased exposure to environmental heat for outdoor workers. Unscheduled or emergency repair practices are associated with different temporalities, meanings, and embodied experienced. Occurring at any time, such repairs engender a heightened sense of urgency in crews, leading to an increased pace of work (exertion) and thus exacerbating heat experiences.

The temporalities of particular performances of work were also the result of articulations between conflicting meanings. Worker safety is one key parameter and value in repair work practice that can be differently articulated, as in these two examples:

> [T]here's never a job where you couldn't come down and anyone would frown upon [you coming down] because you felt thirsty or you started feeling a bit funny (Blake).

> I know [the company says], "Oh, yeah, you can stop," but then you get the public [. . .] complaining: "What are they all doing sitting around?" (Bill)

Crucial to whether workers were able to rest, and thus whether heat stress emerged, was which value or meaning "won out"—worker safety or customer satisfaction—in any given practice performance. Although there are strongly entrenched cultural values and political economies at play here (Rickards and Oppermann 2018), which takes precedence is not determined by an overarching, static value system, but rather by how the relationship between the different possible meanings of a practice activity, such as rest (e.g., as being safe, or being lazy), were articulated in any given performance of work in a specific context. For example, concern about public opinion was heightened in locations where the repair was visible to the public, such as on a busy road, or where the repair was unscheduled and therefore more likely to trigger public frustration and criticism. In these situations, two workers noted they had "pushed on" while feeling symptoms of heat stress instead of stopping to cool down. By contrast, in situations where more significant safety meanings were present, such as knowledge of the heightened and immediate risk of injury or death during "live" electrical repairs, workers more actively utilized safety meanings (including formal and informal protocols for managing body heat and heat stress) and competences (such as embodied awareness of mental and physical fitness) to determine the pace and timing of repair performance:

> For live-work you've got to be definitely more on the ball. So if you do not feel that you're [all right] you've got to speak up for sure. (Blake)

For managers, such considerations were also explicitly connected to political economies, namely, the need to balance heat-affected safety, worker-hours, and productivity with the costs of repair and the values and requirements of the state government, the public, and, more recently, the Australian Energy Regulator.

Working every day in hot and humid conditions, experienced workers like Zac and Shane felt they had developed a strong bodily awareness of heat and heat stress. This competence enabled them to practice work in a responsive fashion. In publicly visible or urgent repairs, they used their bodily awareness of how much heat they could handle to push their bodies to work longer or harder. On the other hand, in low urgency or low visibility repairs, they might more actively manage heat through resting, seeking shade or air conditioning, or ingesting ice (Brearley et al. 2015) to prevent or respond to symptoms of heat stress (such as feeling thirsty or having a headache) more quickly. However, this same awareness was also used to monitor and support capacity to continue working in high-risk or urgent situations.

The competence of listening to and assessing one's body allows workers to engage in the practice of adaptively preempting, preparing for, or recovering from heat stress. Such a practice is a highly complex adaptation played out at an apparently mundane, everyday scale. Workers are not only adapting as individual bodies or in their constant behaviors. Rather, these occur as effects of the embodied practices of practitioners constantly "doing what makes sense" (Schatzki 2010), which, in this case, is adapting practices of work in relation to changes in the array of practice elements (including changing weather) that differently produce, expose, and recover workers from heat and heat stress.

e. *Everyday adaptation and adaptive practices*

Despite heat impacts being openly talked about and explicitly managed within the utility company involved in this study, there was still a sense that work practices were not sufficiently adapted to the seasonally extreme weather. Several interviewees mentioned striking heat stress effects, such as the following:

> And then other times, we've come back to the workshop, and people have been literally exhausted. Believe it or not, it's very common. Even just recently, as the wet [season] just gone, people will come back from work, and go home, and go straight to bed. (Bill)

For practitioners like Bill, such effects had negative meanings and were an impetus for further, deliberate practice change. For others, these impacts were normalized, attributed to inescapable effects of environmental conditions:

> I know I go home [once every week or so] and I've got cramps and all sorts of stuff, and sometimes you're not able to put enough water into you. It's just something you've got to deal with. (Zac)

These physiological effects of heat stress such as exhaustion and cramps were part of the physical materiality of work practices, articulated as undesirable, but not necessarily as avoidable. This might be termed a form of maladaptation (Barnett and O'Neill 2010) if worker well-being is the primary objective. However, there is no necessary moral or ethical shape to work practices. This observation reveals a twofold utility of a practice approach. First, the active incorporation of ''negative'' effects into practices of work demonstrates how work in its current form assumes and depends on these effects and meanings to continue. Second, these effects are *not* necessary, but coconstituted through the particular configuration of work practices, and therefore could be avoided or reduced by varying practice elements and relations between them.

In different ways and to varying degrees, practitioners knew what combinations of elements produced negative effects. ''Self-monitoring'' was often mentioned in association with maintaining body heat balance during work (e.g., Zac, Shane, and Blake). As a concept, this acknowledged some of the embodied competences and experiential knowledge of workers, but it also enacted an individualizing form of responsibilization—that is, making them individually responsible for risk management (Welsh 2013; Nadesan 2010). In practice, self-monitoring was married with ''looking out for'' other crew members, by observing their symptoms, ensuring they were hydrated, and enabling them to rest and recover. However, such monitoring (of self and others) is only effective at managing heat if other necessary practice elements are in place. For example, the practice of ''rotating'' into different roles (with more or less exertion) to manage heat accumulation/loss often utilized the role of safety ''observer,'' which was always part of any job and which did not require much physical activity (Zac; Shane). Similarly, observers had some freedom to use any incidental shade at the repair site provided they could still maintain close visual and verbal contact with the task they were observing (George; Zac).

The contingency of such elements means that the practices of power network maintenance are always dynamic and ''adaptive'' to a degree. Modulating elements in localized and experientially adapted practices enabled not just an ability to weather the weather (Vannini et al. 2012) but to weather work and work the weather (Oppermann and Walker 2018). However, if there is limited ability to change the elements of a practice, it may be performed closer to the edge of what workers can tolerate safely, or the boundary of what negative effects are ''acceptable'' may be moved. Both approaches allowed practitioners to ''do'' work in extreme weather, but what work ''is'' changed dramatically as a result, with significant implications for how extensive and successful adaptation is considered to be.

The practices of power network maintenance in Australia's monsoon tropics represent a dynamic balance between conducting repairs and managing body heat. The ability of practitioners to ''successfully'' balance heat and repairs was related to practice variation and the articulation of available materials, meanings, and competences, including those that arose as a produce of exposure and experience. These everyday dynamics of work are not usually considered adaptation, yet it is these microadaptations that have enabled the practice of repair work to continue beyond recommended environmental thresholds over days, seasons, and decades.

5. Discussion: Rethinking everyday exposure and adaptation through social practices

The climate adaptation literature on extreme heat is often discussed in terms of ''impacts'' as if there is a unilateral relationship between heat and work. Examples note productivity is substantially affected in hot and humid conditions, and that mistakes, incidents, and accidents also proliferate (Dash and Kjellström 2011; Hanna et al. 2011; Lundgren et al. 2013; Tawatsupa et al. 2013; Xiang et al. 2014). In climate change scenarios, such accounts have painted a powerful picture of catastrophe, including naming extreme heat as the greatest financial cost of climate change (Sahu et al. 2013). While these impacts are very serious, like the environmental threshold approaches to occupational heat that they draw on, they take on a deterministic flavor. Through our discussion of social practice theory illustrated by the pilot study above, we have demonstrated that heat is coproduced by, and contingent on, everyday practices. That is, rather than heat impacting work and worker health, heat (and heat stress) occurs *through* practices of work.

This leads us to suggest that outdoor, working populations' adaptations to heat are situated within practices of work in three senses. First, for the particular combination of practice elements that produces heat, these practice elements and their relationships are the site of practice-based adaptation. Second, although dangerous if not carefully managed, exposure to hot environmental conditions is in fact one of the means through which experiential knowledge and bodily competence is developed, a crucial component of developing more adapted and adaptive practices. Third, bodily exposure and available practice elements are shaped by the timing of work practices and their synchronization with other practices, such as domestic electricity consumption. Attention to bodily competences in how to "manage" heat, to available practice elements, and to the timing and synchronization of practices provides a nuanced conceptualization of how heat and heat stress are coproduced, enabling us to see how it is that practitioners manage extreme environmental conditions (beyond externally designated thresholds) and highlighting opportunities for deliberate adaptation *in* and *of* practice.

This study has demonstrated that outdoor work practices represent a *dynamic balance* between the objective of completing a repair as soon as possible while limiting body heat accumulation within bounds that workers can physically and mentally tolerate. Adaptive capacity here is an embodied response to everyday exposure to extreme conditions. This plays out in complex ways in relation to physiological accounts of adaptation. One of the mainstays of thermal physiology is that acclimatization to different environmental conditions requires frequent exposure (Mitchell et al. 1976). In cohorts similar to those of this study, the daily exposure of workers to extreme conditions for 6 months of the year was noted as enabling a degree of physiological acclimatization (Brearley et al. 2016).

In their own estimations of the time needed to adapt, interviewees noted that

> we [new workers] are not expected to work as hard as the guys that are acclimatized and are used to it, until we're [here for] a year or two (George).

This is much longer than the typical recommendations of the time individuals need to physiologically acclimatize. It may indicate that, in addition to physiological acclimatization, a learned, social form of acclimatization—adaptation—to working in a harsh environment may also be crucial to avoiding heat stress. Understood through social practices, there is an intimate relation between acclimatization and adaptation through practice. Everyday adaptation requires the recalibration of practices in response to the strain experienced by the body, weather, and repair tasks. Managing heat balance in relation to these seems to be achieved through changes in knowledge, embodied experience, and actions. Both physiological acclimatization *and* practice adaptation then can occur *through* regular and routine exposure to extreme conditions. This mode of experiential learning necessarily takes place beyond environmental thresholds and is one route to practice adaptation.

The power network maintenance crew in our study did not utilize environmental thresholds when working in hot conditions. While extreme conditions were a starting point for the study, our account of the practices of working in extreme heat demonstrates adaptation policy should not simply resort to either 1) ignoring the threshold because it is consistently crossed or 2) raising the threshold to accommodate average local environmental conditions and acclimatization. Instead, we have taken seriously the argument that, under extreme conditions, physiological adaptation must be considered in conjunction with social adaptation (Hanna and Tait 2015), which we identify as coproduced. We have explored this through the proposition that everyday adaptation (including in complex relations with physiological acclimatization on which some environmental thresholds are based) arises through practice variation and adaptation. As such, we have tried to look at how the "actual" threshold for working in the heat emerges dynamically from environmental heat as just one material element of a broader practice, and body heat as something that is produced, accumulated, or released through practice.

Understanding heat through work practice helps to explain why simply stopping work at certain thresholds can have unintended effects. One example is that in which workers respond to thresholds intended to protect them from exogenous heat by working harder (and producing endogenous heat) in responses to anticipated stop-work orders (Lao et al. 2016). As a result, threshold-based approaches could prevent successful adaptation in two ways: first, by preventing managed exposure to increase acclimatization and adaptation, and second, by disallowing experiential knowledge or embodied competence from being used and enabling workers to adapt to heat by working *differently*.

In the case-study organization, practicing work differently was evidenced by changing the pace or rate of carrying out a task, rescheduling tasks, rotating staff through roles with high exposure and/or exertion, using different equipment to modify physical exertion, and actively cooling rather than necessarily accepting productivity losses, heat stress, or heat illness. If heat and heat stress can be actively accumulated/lost *through* work practices, and if we look at *how* work produces heat or enables cooling, and how exposure and exertion occur and why, these areas present adaptation opportunities integral to *how* work is done rather than allowing environmental thresholds to dictate *if* work is done or at what rate. An example would be using ice ingestion ''on the job'' to reduce body heat or rotating staff through high exertion roles rather than slowing or ceasing work (Brearley 2012, 2016).

The everydayness of extreme heat in Australia's monsoon tropics has provided a fruitful context to explore how work practices adapt and can be inherently adaptive. The constant active trading of exposure, exertion, and thermal energy to keep bodies safe and work ongoing highlights the dynamic nature of the practice of power network repair in extreme conditions. Furthermore, as practices are always adaptive and adapting, we can build on these inherent properties to account for adaptation as a process undertaken *in practice* rather than as a reaction to an exceptional or future event during which known, everyday activities cease or are dramatically altered.

6. Conclusions: Rethinking thresholds in weather, work, and climate change adaptation

Increasing heat extremes is a key impact of climate change, but Australia's monsoon tropics seasonally experience conditions beyond extreme heat thresholds. We have used a study of outdoor work in the region to problematize dominant heat management and adaptation policies that utilize such thresholds to trigger heat stress mitigation strategies. The latter approaches establish unhelpful binaries between climate impacts and adaptation, exposure and sensitivity, and work and rest, obscuring the way in which heat and heat stress emerge through practices of work themselves. Drawing on theories of social practice, we have illustrated how this coproduction between bodies and environmental conditions is mediated by practices and variation in practice performances. Such practices offer valuable locations for learning and adaptation. The heat that matters for adaptation is coproduced by practices in the bodies that perform them, and as such the nature of these conjunctions is the stuff of adaptation itself.

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