**People as Penguins:
Thermoregulation as Part of the Human Essence**

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It is by now well known that having a higher quality social network leads to a happier, healthier, and longer life. One of the best known meta-analyses shows that the quality of one's social network is an even more important predictor of longevity than for example obesity, exercising regularly (or not), and as significant as smoking (or not; Holt-Lunstad et al., 2010; see also House et al., 1988). It is also often said that relationships help us prosper because they help fulfill what has been called a *need to belong*. This need to belong has been understood as a biological urge to be connected through loving and caring relationships (Baumeister & Leary, 1995; Bowlby, 1969). Yet, fulfilling a “need to belong” is hardly a satisfying answer to the question *why* belongingness is so essential for making us thrive. A need to belong is something we intuitively understand – being with other people. But if we think about other animals, like penguins, is a “need to belong” really so essential to help them survive and thrive?

That leads us to the question why relationships make us thrive the way they do, and what makes the need to belong part of the human essence? Often the answers to questions that seem to be the most profound are those that are surprisingly simple. Because a rather essential part of the human essence is staying alive, so what is more crucial and more obvious as a biological urge than that which is required to do to keep us alive every single day? In this chapter we reason that thermoregulation – the regulation of body temperature – is essential not only for staying alive, but also an essential feature for the human need to belong and for social integration more generally. Specifically, we identify basic patterns in how thermoregulation relates to social cognition, and how – as a result – more complex social integration affects our core body temperatures.

Our perspective suggests that humans are, in one important way, just like penguins: We need warmth and a good huddle when we are cold in order to survive. Yet temperature affects our social behavior in even more complex ways. Warm environments, for example, elicit greater conformity in horse race-betting (Huang et al., 2011). Furthermore, houses – which protect us against the cold – are regarded as more homely while we are more likely to purchase them when temperatures are low (Van Acker et al., in press). Moreover, customer service employees become friendlier when temperatures drop (Kolb et al., 2012). All of these findings are all part of an area of research that has been aptly called *social thermoregulation* (IJzerman et al., 2015a). How can they be organized so that we understand how and why temperature has become part of our needing to belong?

In this chapter we provide an overview of the domain of social thermoregulation. Our overview suggests that humans have always relied on, and still rely on, thermoregulation to navigate their social environment. In outlining social thermoregulation, something that we share to some degree with other species, as a crucial feature of the human essence, we focus on the continuity of thermoregulatory mechanisms from other animals to humans. We then provide a number of different effects from the social psychological literature that helps us understand how thermoregulation is implicated in social behavior. From there on, we seek to understand our brain as a “hierarchically organized prediction machine” that helps us keep temperature at optimal levels. By then, it should be clear how thermoregulation is part of our human essence, how it changes our thoughts about others, and alters our motivations to be with others. We end by pointing to the implications of understanding thermoregulation as human essence.

Thermoregulation in the Animal Kingdom

The knowledge base of thermoregulatory mechanisms in the animal kingdom is vast: Between 2011-2015 alone an estimated 9,000 papers were published on thermology and temperature measurement (Ammer, 2014, 2015). Our aim here is not to provide an exhaustive review, but to instead distil the core conclusions from this work and the perspective on human essence it implies. In doing so, we assume that despite that other animals are different from humans in many respects, and suggest that there is still a good amount that remains to be learnt from species that are related to us, how distant evolutionarily they may be.

Broadly speaking, animals seek to keep them safe in order to survive, and mismatches between “desired states” and influences from the environment lead the organism to act. This simple principle also holds for thermoregulation. If environmental temperatures rise or drop precipitously, recognition and then regulation is required. In learning basic thermoregulatory mechanisms, the distinction between *poikilotherms* (cold-blooded animals) and *homeotherms* (warm-blooded animals) is helpful. Fundamental differences exist between poikilotherms and homeotherms in terms of how they regulate their body temperature: Poikilotherms solely rely on the environment to regulate their body temperature; homeotherms also do so internally. When poikilotherms’ temperatures rise or drop outside of comfortable ranges, they gravitate towards more comfortable environments. Homeotherms on the other hand have more complex systems to detect and regulate temperature. This regulation can be understood by what Walter Cannon (1932) called “homeostasis”: Keeping stable internal physiological features, even when the external environment becomes more instable. Warm-blooded animals strive for “thermal” homeostasis by keeping their internal physical circumstances as constant as possible.

In maintaining homeostasis, homeotherms mount a number of internal defense systems. In case of temperature increases, they can sweat, pant, or yawn (e.g., Gallup & Gallup, 2008) and

when temperatures drop they can shiver (Yanský, 1973). There is a considerable asymmetry here: Temperature rises are typically resolved by the organism itself (either through internal regulation or by simply jumping into a nice and cold pool) as not being able to do so quite rapidly can cause death or permanent brain damage. Temperature drops on the other hand are not immediately threatening to the organism: Only when temperature drops threaten the core they are likely to become threatening for survival or for brain functioning, and this occurs much more slowly than when temperatures rise. As a result, temperature drops (but not increases) can be regulated while relying on the environment, which can be other animals. .

What is more, this internal regulation mechanism confers homeotherms with an added advantage: It allows them to be much more *flexible* in choosing the environment to live in. However, internal regulation mechanisms come at a cost: Ask anyone that comes out of ice cold water. When temperatures drop, animals start to metabolize and “spend” energy to warm up through for example through shivering. Shivering counts as one of the most energy-costly bodily processes and thus is expensive (King & Farner, 1961); it may then also not come as a surprise that animals seek to *economize* thermoregulation, so that body thermoregulation is done as efficiently as possible (Nuñez-Villegas et al., 2014).

As we have noted, temperature drops do not immediately threaten survival or brain functioning. This allows homeotherms to rely on fellow animals for thermoregulation. The result for homeotherms is that many of them live in groups to distribute the risk of cooling down, and not only to avoid the risk of being eaten (for those that live in contexts populated with conspecifics). Many homeotherms have thus started relying on other animals to distribute and economize the costs of thermoregulation across conspecifics.

Experimental rodent research has suggested a first hint to this energy-saving hypothesis for homeotherms: The Octodon Degus' (a Chilean rodent) energy usage at 15 degrees Celsius is 40% lower and surface temperature higher when housed with three or five (vs. alone; Nuñez-Villegas et al., 2014). This causes *social thermoregulation* to be part of homeotherms' essence, as one article reviewing rat research shows that social thermoregulation is one core reason for why homeotherms live in groups (Ebensberger, 2001). And in different species we can also observe mechanisms that are in place to let conspecifics help in survival, and which therefore help thermoregulation become part of their essence. For example, example, cows and pigs cry or shriek to call their fellow farm animals closer in case temperatures drop and they are in need of a solid huddle (e.g., Hafez, 1964).

This suggestion has important implications. For one, if other animals indeed help their ilk to keep warm, one might expect physiological and cognitive mechanisms that help us understand who can be relied upon to do so. This is where animals are often set apart in terms of how complex thermoregulatory mechanisms have become (and obviously the sole way that we can distinguish penguins from humans). More specifically, we observe an increase in complexity of thermoregulatory mechanisms via which animals control their temperature when we shift to animals whose social and physical environments are more complex.

Consider a species called *vervet monkeys*, a monkey native to Africa, and one that is often used to understand human behavior. Researchers observed these monkeys at the Eastern Cape in South Africa and counted the number of other monkeys they interacted with. What the researchers found is that the core temperature for those with larger social networks remained higher when the monkeys' social networks were larger (they had a smaller amplitude; McFarland et al., 2015). This means that the monkeys somehow "know" that they can rely on other

monkeys, as their own bodies exert more energy to stay warm. We will return to which mechanisms are in place for those monkeys later, when we return to the idea of a “layered” system of thermoregulation.

In conclusion, it is pretty clear that environmental and internal regulation mechanisms exist to regulate temperature. Furthermore, it also is becoming very apparent that social contact has become part of the animals’ bioenergetic regulation systems and that social contact helps homeotherms to maintain temperature homeostasis as efficiently as possible. It logically follows that some mechanisms *have to be* in place to help estimate how reliable the social environment is, as this confers the animal with ever-greater flexibility to adapt to novel environments. We now first direct our attention to research on thermoregulation in humans, and then direct our attention to those mechanisms that help estimate how reliable our social environment is. From there, we will return to the *need to belong*, so that we can start to comprehend why thermoregulation has become such an essential feature of the human essence, and why social proximity and social soothing have become what we call *unconditionally reinforcing* (i.e., innately motivating).

Human Social Thermoregulation: You, Penguin?

It is easy to argue, at this point, that current humans no longer depend so much on social thermoregulation: Whether it is clothes, a thermostat, a shower, or a personal heater around the wrist, we know how to warm ourselves up and cool off when need be. But please remember that these inventions are relatively novel in terms of our evolutionary history – from this perspective, it is quite likely that many of the biological and cognitive systems that we use for navigating our social environment have been formed over many years of evolution without all these novel thermoregulatory devices. Two questions are therefore important to address: Is

temperature at all involved in navigating humans' current social world, and, if so, how did it become involved in our social motivations and in our thoughts about others?

As for the first question, although the field of social thermoregulation is very much in its infancy¹, it is becoming clearer and clearer that thermoregulation is involved in our social behavior. Since 2008, when the first report on the topic was published, approximately 83 reports appeared at the time of writing this chapter on thermoregulation and social behavior. One of the first reports was published by Lawrence Williams and John Bargh (2008), who found that after participants held a warm (as compared to a cold) cup, they judged others as more sociable and trustworthy, and became themselves more generous. This suggests that a temperature cue distorts our thoughts about others and behaviors towards others in important ways.

There were many reports in the scientific literature that followed, and the effects researchers found on motivations and social cognitions varied widely. Some very basic effects indicated that people pay more attention to relationships when they are warmer. Participants in these studies for example, used more language associated with feeling psychologically closer to others and they tended to see more relationships in very basic figures when in a warm (as opposed to a cold) condition (IJzerman & Semin, 2009). Similarly, when people were in warmer conditions they show more conformity to the group. For example, when it gets warmer, people bet on horses that are more popular with the “bookies” (Huang et al., 2011).

¹ It is certainly worthwhile mentioning that these effects have not been without criticism, as some effects in this literature are (Schilder et al., 2015) and others are not replicated (Vess, 2012; LeBel & Campbell, 2013). The psychological literature in the last few years have seen a large overhaul in terms of what is considered reliable and solid evidence, and rightfully so. What is often the case is that psychological studies are heavily “underpowered” (i.e., participant samples that are too small to be able to support the tested hypothesis). Although this may be true of some of the reports in this literature, solid evidence certainly exist, with a considerable amount of studies with participant samples between 100-500, and some outliers even with samples around 30,000 and above 6 million. Though the criticisms are well-taken, we suspect that criticisms for this field should be mostly directed at measurement and picking the right variable for the right situations.

To what degree is this part of the human essence, and do we as humans still apply thermoregulatory mechanisms to our non-social environment? The literature suggests that we do, as temperature remains a cue when we observe robots, which we view as more humanlike and friendly when they are physically warmer (Nie et al., 2012), while we also connect warmer temperatures to products we perceive as more trustworthy (IJzerman et al., 2015b). This thus suggests that thermoregulation has become truly essential to the human essence, and likely the underlying motivating mechanism for our need to belong.

Yet, the effects are not as straightforward as they seem. While many of the effects seem to show a positive link between warmth and prosocial behavior, customer service employees are friendlier in colder environments (Kolb et al., 2012), while people rent more romance movies (but not more movies overall) when they get colder (Hong & Sun, 2012). Furthermore, people find a house more “homelike” and want to pay more for it when it is colder. These tendencies seem to be driven by people’s motivations to be with others when they are colder (Van Acker et al., 2016). Altogether, this seems to suggest that we are *motivated* to be with others when it is colder, while our *thoughts* are more likely to be prosocial when in warmer environments.

We can conclude that thermoregulation is deeply integrated into our thoughts about others and our motivations towards others in interpersonal situations. In further understanding these effects, it helps specifying individual differences as to how people rely on thermoregulatory cues. We will address this idea in the next section, where we illuminate how thermoregulatory cues help us navigate our social environment by making predictions about other people.

Human Cognition: Meet Our Brain, the Prediction Machine

The tendency to affiliate with others can also be detected when we look at people's memories of others: When participants are put in physically colder conditions, they are more likely to think of loved ones than in warm conditions. However, this memory of others is driven by their past relationships experiences with, and thus predictions about, other people (IJzerman et al., 2016a; see also Fay & Maner, 2012). This individual difference in what kind of predictions we make about others can help us specify what the central mechanisms are guiding and regulating temperature and social world, and how this sets apart the human from the penguin essence.

Crucial to understanding human social thermoregulation – and where it sets the human essence apart from many other animals - we believe, is the *value* of temperature cues in predicting the reliability of our social environment. Some of the effects may indeed be confusing: Warm and cold conditions may sometimes give rise to being more and sometimes to being less friendly. How can we resolve this puzzle in understanding how thermoregulation factors into our social behavior? Although there is still much to be learnt about the exact mechanisms, there are a couple of heuristics we can adopt. Essentially, (a) others help us to warm up (not cool down), (b) our cognitive systems should function in such a way that it helps us predict to what degree others can reliably warm us (and that we feel warmer when we think someone is more trustworthy). Thus, (c) when we are (comfortably) warm, we feel trusted and will be more generous, but (d) when we are cold, we are motivated to seek out other people (or consumer brands or houses), and we do so when (e) we learnt that others reliably warm us up.

Furthermore, we rely on temperature to navigate our social environment. When we are reminded of the fact that others are trustworthy (and thus *socially predictable*), we feel warmer; that is, when we are put physically closer to another person, or even when we are reminded of

trustworthiness, we perceive temperatures as higher (IJzerman & Semin, 2010). On an even more abstract level, when we are reminded of a consumer brand we associate with positively, our temperature perception also goes up (IJzerman et al., 2015b). Thus, temperature-dependent social behavior is not solely applicable for huddling with one another, but it extends to what kind of predictions we make of others. Perhaps the most sophisticated example is a recent finding that people living further from the equator (typically taken as a proxy for a colder climate) have more diverse social networks, and these diverse social networks protect people's core temperatures from the cold (IJzerman et al., 2016b). And *only* those who have a romantic relationship get access to those more diverse social networks. In other words, being able to cuddle everyday with a partner – like a penguin - allows one to profit from “more advanced thermoregulation” – something that probably not penguins, but most humans seem capable of doing.

As a more general overview of how the brain relies on temperature predictions to navigate the social environment, the person who best summarized what we need for understanding this complex relationship is the cognitive scientist Andy Clark (2015). He called our brain and body a “multi-layer probabilistic prediction machine” (Friston, 2009). These multi-layer predictions go from relying on basic mechanisms in the body (like cuddling) to more advanced long-term predictions (knowing that one can rely on one's social network). Over evolutionary time, more novel systems likely developed that allow us to make predictions about others, and these rely on the same brain mechanisms that helped us knowing who could warm us. Early on, animals could simply move to a different environment to warm up. Over evolutionary time more complex regulation mechanisms started to emerge that were either internal and/or social, and helped us become more flexible.²

² Although it may appear that we suggest that homeotherms evolved *further* than poikilotherms, this is not what we intend to say. Instead, homeotherms have become equipped with *extra* mechanisms that afforded them with greater

Throughout most of human history, we did not live in houses, make fire, or model weather conditions days in advance. We always needed to cuddle with others simply to stay warm. We think that this necessity led people to survive who were also better able to predict who would be reliable in warming them up when cold. As a result, brain mechanisms have become assembled in such a way that we have obtained integrated thermoregulatory-social prediction brains (Satinoff, 1978). That is why thermoregulation likely remained an important variable for our brains to make predictions about, and that is why temperature predictions remain important in so many of the social behaviors we engage in day in and day out. It is also why we have integrated thermoregulation into our thinking about our social network, and why (mostly) people that speak Indo-European languages think of emotionally responsive people as warm and emotionally unresponsive people as cold. And it is also what sets the human essence apart from the penguin essence.

Further Distinguishing Humans from Penguins: Thermoregulation is Hierarchically Organized

Again, the mechanisms that have arisen are anything but simple. When we started discussing the basic mechanisms central to thermoregulation, we implicitly and explicitly described a hierarchical view of thermoregulation, with at the lowest level the distinction between animals that make use of their environment versus animals that can also regulate temperature internally. Accordingly, homeotherms have been afforded with an extra feature that makes them more flexible to adapt to new environments. And could it be that even more systems are in place that make animals yet more flexible to adapt to climatically unstable environments?

flexibility to adapt to novel environments. Following such adaptations, both homeotherms and poikilotherms still evolved throughout years of evolution. There are not just advantages to internally regulating temperature: Homeotherms for example are also much more sensitive to the environment, as homeotherms closer to the equator are much smaller, a rule that poikilotherms are much less sensitive to (cf., Bergmann's rule; Meiri, 2011).

After all, recall that vervet monkeys had actual higher core temperatures if they had higher social networks. Could it be that the monkeys get some kind of cue when they are more socially connected, and because of that they get warmer, even when the environment is the same?

There is some research that confirms this. One very “cool” study demonstrated that when they groomed dead monkey pelts, the pelt was much better protected against blasts of warmth or coldness than in an ungroomed condition (McFarland et al., 2016). Thus, the grooming of the monkey likely *changes* the vervet monkey’s perception of temperature, “communicating” that its social group helps in staying warm. Thus, we infer that the socially connected monkey receives (nonconscious) cues that it has a social network to rely on, and, as a result, it can adapt itself better to changing environmental temperatures than the not so well connected monkey. But this is unlikely about “just” warming up, but also about assessing the reliability of the social environment.

In comes the evidence on humans. One of the prime indicators that proximity is at a neutral, and desired, level is body temperature. That is, Fransson, Karlsson, and Nilsson (2005) found that babies have smaller differences between skin temperature and core temperature when being held (vs. when not) potentially preventing hypothermia, and thus *maintaining homeostasis*. Thus, more and more evidence is coming together that thermoregulatory systems are *layered*. From poikilotherms to penguins to monkeys, thermoregulatory mechanisms have become more complex, and layer upon layer the brain and body help protecting against harsher and harsher temperature environments (cf. Caporael et al., 2013; Mandler, 1992).

Consider an even more advanced way of regulating temperature, as in how temperature can bias memory in humans: When a face is paired with physical warmth, we remember the face as friendlier (thus decreasing our need to be with others in our environment), and if it is paired

with physical coldness, we remember the face as unfriendlier (Messer et al., 2016). Furthermore, our skin becomes colder when we are excluded from the social group and we can fool a person's emotional state (at least temporarily) after being excluded by handing them a warm cup to hold (IJzerman et al., 2012).

The view of thermoregulation as guiding our predictions about social behaviors, and thermoregulation as structured hierarchically may help us understand why thermoregulation has remained relevant for more complex social behaviors, like eliciting greater conformity in horse race-betting (Huang et al., 2011). Or why houses are regarded as more homelike when temperatures are low (Van Acker et al., 2016). And also why customer service employees become friendlier when temperatures drop (Kolb et al., 2012). And it should be clearer why people who are more socially integrated have their core temperatures buffered better from the cold. Finally, if we “prime” people with the idea of social predictability, their temperature perceptions should rise (IJzerman & Semin, 2010; IJzerman et al., 2015b; Zhong & Leonardelli, 2008).

Implications for Understanding Social Thermoregulation as Human Essence

Perhaps the reader is convinced that thermoregulation is part of the human essence. But at the end of this chapter, perhaps the question “so what?” is justified. We hope we have made the case for the fact that thermoregulation is still an important motivating factor for our relationships (and, as some have argued, that homeothermy is one of the main reasons why morality has become part of our essence as well; Churchland, 2014). It is thus tempting to quickly intervene in helping us to live a longer, happier, and healthier life. However, our enthusiasm still needs to be tempered, for a number of reasons. First, we know little about its consistency across climatic environments. Most studies that are currently conducted are done in

the Western world, which may not necessarily generalize to other climatic environments. There are some indications that the way that people think about temperature differs as a function of climatic variation, at least as evidenced by linguistic expressions. Metaphors using warmth for affection mostly appear in Indo-European languages and are absent in languages spoken close to the equator (Koptjevskaja-Tamm, 2015). And basic thermophysiology is already complex, let alone its connection to social behavior. Thus, simply holding a warm cup will not resolve our anxieties or feelings of loneliness long-term. Again, it is important to keep in mind that the field of social thermoregulation is only in its infancy.

Even though its application requires much more research, we are hopeful, particularly in relation to health. For example, *Brown Adipose Tissue* (BAT; a type of fat) is not only involved in shivering thermogenesis, but also involved in tumor growth, at least in rats (e.g., Ricquier et al., 1983). Only recently did researchers discover that BAT is not only present in infants, but also in adult humans (Nedergaard et al., 2007). We know that relationships and social support are linked to health, and social support is even linked to recovery from (breast) cancer (Funch & Marshall, 1983; Waxler-Morrison et al., 1991). Could it be that thermoregulation is an important missing link in understanding just how relationships help us survive, even in the face of destructive forces such as cancer? We think so, but we barely know anything about how thermoregulation relates to a disease like cancer, and the mechanisms likely vary per type of cancer.

Thermoregulation can likely also be used to understand the link between relationships and the development of self-regulation. We suspect that maternal thermoregulation links to brain development in the human infant's early days. In rats, longer maternal thermoregulation has been associated with longer brain growth in rats (Suchecki et al., 1993). Along the same lines, rat pups

that had received longer, more intensive maternal care grow up to show a healthier stress response (Weaver et al., 2004). Outsourcing the (metabolically expensive) activity of thermoregulation - and having more “energy” available may well be an important reason why the brain has a longer period to mature with prolonged maternal thermoregulation, and we suspect something comparable occurs for humans. In other words, we think that thermoregulation is such an important part of the attachment system that relationship and attachment interventions should rely on temperature as an *unconditional reinforcer* to help increase social predictability, and to help the infant’s brains to mature. If that were true, would such interventions also extend to adult humans? Interventions are typically aimed at talking about difficult emotional episodes. But could it not instead be that crucial for attachment interventions is linking warmth with social predictability?

We suspect so. We think that social thermoregulation is the reason that the *need to belong* is a biological urge, and one important facet in why relationships are even more important for our health than being obese (or not), exercising (or not), and as important as smoking (or not) for how long we live. Nevertheless, just like that we do not yet fully understand how social thermoregulation motivates us to act in social situations, we still need to set up substantial programs of research before being able to intervene in daily life. But as it may, the answers to these questions are right around the corner: With the advent of modern sensor and actuator technology and advanced statistical analyses, we are convinced that a more advanced understanding of social thermoregulation will help us thrive.

This brings us back to the notion of human essence. For us, clearly what is essential for people is their relationships and their need to belong. But what drives the need to belong is people’s day-to-day challenge to thermoregulate, and it is this part of the human essence that we

share in part with other animals. And perhaps because it is so essential it may have been often overlooked. But the animal, physiological, and psychological literatures all point to one important truth: Social thermoregulation is one important universal for homeotherms that live in groups, and humans do so in even more complex ways. Just how, why, and when we can apply this knowledge of our human essence will only be understood in the very near future.

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