Philosophers' Imprint

volume 23, no. 25
october 2023

Thermal Perception and Its Relation to Touch

Richard Gray
Cardiff University

DOI: *10.3998/phimp.2547*

1. Introduction

It is generally accepted that, when we touch an object with a part of the body, such as the hand, as well as being able to perceive its texture and solidity, we are able to perceive its thermal properties. We feel things to be rough or smooth, hard or soft, and hot or cold. That we seem to experience these properties in the same way has been taken to support the view that thermal perception is a component of the sense of touch (Fulkerson, 2014, 2015; Matthen, 2015; Ratcliffe, 2012). However, such experiences are also enabled in otherwise different ways, in particular by means of different physical stimuli and different kinds of sensory receptors. This has been taken to support the contrary view that thermal perception is distinct from touch (Gray, 2013; de Vignemont & Massin, 2015).

One response is to deny that the two views are in conflict. It can be agreed that thermal perception is enabled by thermal stimuli that provide us with access to the thermal properties of things, whereas pressure perception is enabled by pressure stimuli that give us access to the solidity and texture of things. But we can also hold that thermal perception and pressure perception jointly constitute the sense of touch (Fulkerson, 2014; Matthen, 2015). In this paper, I focus on another difference between pressure perception and thermal perception that cannot be dismissed in this way: the capacity of pressure perception, but not thermal perception, to facilitate the perceptual experience of the tactual properties of distal objects, objects with which we are not in direct contact. I maintain that this difference cannot be easily dismissed, not just because the dissimilarity between thermal perception and touch is more substantial, but also because it reveals a disparity in the apparently similar ways in which the properties of the proximal objects we touch are perceived.

Touch is usually characterized as a proximal or contact sense as opposed to a distal or teleosense, such as vision or audition. One influential way in which this has been developed is the characterization of touch as a template sense. On a template view of touch, bodily awareness acts as a template for touch (see O'Shaunnessy, 1989 and Martin, 1992). It is through the sensed modification of a part of the body that we feel the tactual properties of objects.[1] I am skeptical of a template approach to thermal perception. Here, I defend the claim that thermal experiences, in general, directly represent the heat that is transferred to or from the surface of the body rather than the thermal properties of either the body or other objects.[2] My primary focus, however, is on the more general characterization of touch as a proximal sense, which has recently been disputed. Citing plausible cases in which tools are used to perceive distal objects and their tactual properties, Fulkerson (2012) has argued that the distinctive nature of touch is better characterized by a *Connection Principle* (CP). We can feel the properties of distal objects by touch because tactual information can be transmitted via a tactual medium; we can have a connection to the objects through appropriately constituted media. Hence, touch is better regarded as connecting us to whatever is felt by touch, whether it is a distal or proximal object.

I argue that, whereas the Connection Principle is satisfied by touch in so far as it is satisfied by pressure perception, it is not satisfied by thermal perception. Tools cannot be used to mediate information about the distal thermal properties of objects in the way that they can be used to mediate information about the distal tactual properties of objects. And, although thermal experiences can be caused by distal objects without a tactual medium, such thermal experiences do not enable perception of what causes them in the way that tactual experiences enable perception of the distal properties that cause them via tactual media. This suggests two things: first, the content of such thermal experiences is not a thermal property of an object but the heat that is transferred to a part of the body, and, second, thermal perception and touch involve senses of different kinds.

This opens up a different perspective on the qualitatively identical thermal experiences caused by the proximal objects we touch. According to a plausible thesis about the nature of experience, if two token experiences are qualitatively identical, then their phenomenal contents are also the same.[3] Granting such a view, it follows that the content of the qualitatively identical thermal experiences we have when we touch objects is the heat that is transferred to the part of the body touching the object. This view is supported by the physics of heat, which tells us that heat is transferred in both cases, by physiology, which tells us that individual thermal receptors do not distinguish between types of thermal stimulation, and by the lack of plausible candidate thermal properties of objects to explain our thermal experiences. The upshot is that we do not feel the thermal properties of objects as we do their tactual properties. We feel the texture and solidity of objects and the heat that is transferred to or from the skin. But if this is right, an alternative account is owed of how we come to know the thermal properties of the objects we touch, their hotness or coldness, which we surely do, and what these properties are.

The paper is ordered as follows. In §2, I set out Fulkerson's account of touch without touching. In §3, I show that the perception of distal thermal properties is not possible in this way, concluding to the

1. The tactual aspect of an experience in which the object is felt by touch is sometimes referred to as the "distal" aspect, as opposed to the "proximal" aspect, in which a modification to a part of the body is sensed. When I use "proximal" and "distal" in this paper, unless otherwise specified, I use them to refer to objects of perception that are either in direct contact with the body (proximal) or not in direct contact with the body (distal) and to the senses related to the respective objects.

2. See Gray (2013). In so doing, I am at odds with Fulkerson's (2014, chapter 4) view, according to which tactual, including thermal, properties of things are perceived by way of an implicit experience of bodily awareness. I do not deny that thermal experiences represent the location on the body where heat is transferred and to that extent imply an awareness of the body, but I do not think that thermal features of the body are also represented, nor, a fortiori, are they used as a template for the representation of other thermal properties.

3. Phenomenal contents are those contents of an experience that are exhausted by how they appear. By framing the claim in terms of phenomenal properties, the possibility of differences in other perceptual contents remains. For instance, experiences of two qualitatively identical items will have the same phenomenal contents but, on some views, also have different contents, because the two items are distinct. Hence, the phenomenal contents thesis can be accepted by a range of views in the philosophy of perception. The thesis might, however, be challenged by advocates of qualia, who can hold that different qualia could be related to the same phenomenal properties.

contrary that thermal perception is a proximal sense and that the content of the thermal experiences caused by distal objects is the heat that is transferred to a part of the body. In §4, I argue that the thermal experiences caused by things we touch should be understood in the same way and so do not meet Fulkerson's Connection Principle as touch does. I claim that thermal experiences can, nevertheless, justify beliefs about the thermal properties of objects we touch without being about those properties, because there is a constitutive link between those properties and the heat transmitted to and from the skin that is detected by thermal experiences. In §5, I set out an account of the thermal properties of objects and why we do not feel these properties. §6 concludes.

2. Touch Without Touching

The term "touch" has a well-known ambiguity. Two physical bodies touch just in case there is physical contact between them. So "touch" refers to what takes place when contact is made between our bodies and other physical objects: they touch. The term "touch" is also used to capture how the properties of the things that are touched are sensorily experienced. It is easy to see why the sense of touch should be considered a proximal or contact sense if the way in which we sensorily experience the tactual properties of things is aligned with the contact made between our bodies and other physical objects. The view that the sense of touch is constituted by the contact that occurs when we touch things is termed the Contact Thesis (CT) by Fulkerson:

> **Contact Thesis (CT)**: Tactual object perception occurs only at the surface or limit of the body; reference to an external object in touch occurs only when the object is in direct contact with the body. (Fulkerson, 2012, 2)

It is no surprise that the sense of touch is contrasted with the senses of vision and audition if the tactual perception of an object is taken to be possible only when there is direct contact between the surface of the body and the object.

There are, however, well-known counterexamples to the CT. For example, we are still able to feel things through items of clothing when direct contact is not present. We can feel an object by touch while wearing a glove. It is not the glove that we primarily feel but the object in contact with the glove. We can also feel the floor that we are walking on when we are wearing shoes. More radically, we can feel things and their tactual properties situated at a distance from our bodies by means of tools, such as walking sticks. Indeed, Fulkerson points out that we can even feel the road that we are driving on. For this reason, he has proposed a different way of characterizing the distinctive nature of the sense of touch that does justice to distal touch. According to his Connection Principle (CP), the sense of touch involves an appropriate tactual connection with an object:

> **Connection Principle (CP)**: Tactual reference to an object requires an appropriate tactual connection with the object, either directly or through some intermediary. (Fulkerson, 2012, 6)

This can accommodate both the standard notion of a contact sense and the way in which touch can inform us of distal tactual properties.

Significantly, when the connection is made through an intermediary, the intermediary must be such as to be able to convey information about the tactual properties of distal objects. Walking sticks provide an appropriate tactual connection with objects with which someone is not in direct contact, because their rigidity allows the resistance felt at the end of the stick and caused by an object, and even the more fine-grained features of an object, to be transmitted reliably via the stick to the person holding and moving the stick. The driver of a car can feel the surface of the road via the car that they are steering over the road surface, because the car is able to provide an appropriate tactual connection with the road surface. In such cases of distal touch, we do not feel the distal object to be in contact with the body. Rather, information from the distal object is transmitted to the sensory surface of the body via a medium that remains largely implicit except where it makes contact with the body. Contrast these examples with a slack rope, which does not convey any information about the properties of the objects to which it may be attached. Other tactual properties of distal objects, such as weight, can be detected in other ways. Consider how we can tell how heavy an object is by how easy or difficult it is to swing it when it is attached to a rope.

If in touch we can perceive distal tactual objects largely without perceptually experiencing what it is that connects us to those objects, then touch resembles vision and audition: we can perceive visible and audible objects without perceptually experiencing the physical features that connect us to those objects. In this respect, touch is just as much a teleosense as vision and audition. Nevertheless, there is a significant difference between touch, on the one hand, and vision and audition, on the other. Apart from the sensory feel of the medium at the point of contact with the body, the CP captures a relation that is mutually interactive, as Fulkerson notes. We can detect the tactual properties of distal things by means of sticks or cars because of the interactive nature of the relation between the body and the external environment. We move sticks and we steer cars with respect to objects that resist their motion. Hence, touch is better regarded as falling between a teleosense and a contact sense. It is a connection sense.[4]

As well as thinking that touch is better characterized by the CP than by the CT, Fulkerson also maintains that thermal perception is a component of touch.[5] Indeed, he takes the view that the structure of touch is comparable to that of the visual and auditory senses:

> In haptic touch, the various cutaneous and kinesthetic activations are coordinated (temporally, spatially, and otherwise through exploratory action), resulting in a unified perceptual experience of tangible objects. The unified representations that result are structurally similar to those found in vision and other senses …. Haptic touch thus turns out to be a single modality, its various constituent systems aligned much like those involved in vision, and the other senses. (Fulkerson, 2014, 18)

Tactual perception is taken to be structurally like vision in that the perception of heat is taken to be a component of touch in the same way as the perception of color is a component of vision. However, there is a significant dissimilarity that goes beyond the presence of different physical stimuli, or so I maintain: the thermal properties of things—their hotness or coldness—are not directly perceived in the way that colors are directly perceived. Nor, indeed, are they directly perceived in the way that the texture and hardness of things are directly perceived by touch. Rather, I hold that the thermal experiences we have when we touch hot things are experiences of the heat transferred to the part of the body in contact with the object touched.

To substantiate this claim, I draw on the following plausible theses: qualitatively identical experiences have the same phenomenal contents; the thermal experiences caused when we touch things and those caused by distal objects are qualitatively identical; and the phenomenal contents of thermal experiences of distal objects are the heat transferred to the body. An initial challenge to this line of argument, however, comes from Fulkerson himself, who claims that thermal perception can be distal in the same way as tactual perception. It is this key claim with which I take issue in the next section.

3. Distal Thermal Perception

When we touch something, we seem to feel the thermal properties of what we touch. After all, objects cause us to have thermal experiences when we touch them. Does the same occur in distal touch? It would seem not. When we feel the tactual properties of distal objects through tactual media, we do not at the same time also seem to feel their thermal properties.

4. A further dissimilarity supports the proposed classification. In the case of distal touch, the tactual medium can itself be perceived by touch. The visual and auditory media cannot be perceptually experienced by vision or audition respectively.

5. See also Matthen (2015) for a similar position.

We can feel the way in which tactual properties modify the movements we make with a tool; we can feel the way in which the dent in an object modifies the movement we make with a stick over it and we can feel how difficult it is to swing a weighty object at the end of a rope. Nothing comparable has been shown to enable perception of the thermal properties of distal objects. One reason the thermal perception of distal thermal properties is hard to demonstrate is that thermal information is not transmitted by tactual media in the same way as tactual information. Many tools are simply incapable of transmitting thermal information; they do not have the appropriate thermal conductivity. But, more significantly, where a medium can transmit information about the thermal properties of an object, this is insufficient to enable a thermal experience of the distal object's thermal properties. The thermal experience does not locate a thermal property where the object is, as is the case when a stick is used to detect the tactual properties of distal objects. Imagine holding a metal rod in contact with something hot. A metal rod has the appropriate thermal conductivity to transmit information about the thermal properties of the object. However, whereas one would feel the tactual properties of the distal object, one would not feel the distal object to be hot; one would instead feel the end of the rod that one is holding to be hot. Relatedly, when you touch something hot with gloves on, it is your gloves that tend to feel hot, not what is touched.[6]

At this point it might be argued that we do not need to use tools to detect the thermal properties of distal objects. We can do this without such intermediaries. Indeed, Fulkerson cites such a case to motivate his more general approach to touch as exploratory:

> Consider a simple case of distal thermal touch. With your eyes closed or blindfolded, you can experience the heat coming from a candle set before you. The exploratory actions you perform relative to the candle — perhaps moving your palm around in front of you, feeling for the heat to increase or decrease — allow you to experience the heat as coming from an external source. Located in a particular spot. It is the way in which the experience of the heat changes relative to our movements that secures the distal nature of the experience; we experience the heat as located at a distance from our bodies because our heat experiences are appropriately linked to our movements. (Fulkerson, 2012, 7)

The case under discussion is key to an understanding of distal touch. Hence, it needs to be considered in some detail. First, it is important to blindfold the subject. Eliminating visual information prevents associations being formed between the visual experience of the location of the candle and the variation in intensity of the subject's thermal experiences as they move in relation to the source. It is also possible that vision augments the information delivered by thermal perception of the location of the candle. Moving the hand with respect to the source is supposed to suffice for information about the location of the candle.

First, I do not dispute that, in the case described, one would experience the heat coming from the candle. But it is disputable that the heat is experienced as coming from the candle. To seek to establish this, Fulkerson claims that moving the palm of your hand, which results in an increase or decrease in the intensity of the heat you feel, enriches the content of the experience, taking it from merely being of a degree of heat transmitted to the hand to a degree of heat coming from an external source situated at a particular location. It would be hard to deny that the intensity of the thermal experience varies as the hand is

6. As an anonymous referee rightly points out, this will be more accurate of some gloves than others. Insulated gloves will seem to feel hot after a while, rather than the object held, if they allow heat through slowly. By contrast, thermally non-insulating gloves will allow heat through quickly; they are, as it were, transparent to the passage of heat. Nevertheless, it is not clear that such a case provides support for the claim that the hotness of objects can be perceived via tactual media, given that they constitute a minimal thermal barrier. In other words, wearing such gloves would be more like not wearing gloves at all. We are still owed less controversial instances of the perception of thermal properties of objects that are at a distance.

moved and that we are aware of this. But there is no reason to think that the location of the source is given in the content of the thermal experiences, even in conjunction with the movement of the hands. To determine the location of the candle, one would have to know the intensity of the heat at the source. But one cannot know this merely from perceiving the heat transmitted to the hand, nor from perceiving the way the heat increases as the hand is moved toward the source. Of course one might locate the candle by moving the hand behind the candle. But even this does not show that the location of the candle is given in the experience. It is more plausible to think that the location of the source is inferred, given assumptions about the intensity of the heat of the candle. There is no reason to think that this is part of a perceptual process.

It is not that there is no further information present about the location of a thermal source that could be used by a perceptual modality. It is that the mode of thermal perception that humans possess cannot utilize it. Compare and contrast this with a form of thermal perception where such information is utilized: thermal imaging. Thermal imaging involves dual sensory organs, enabling creatures that possess the sense to detect the distal location of thermal sources in a perceptual field, along with their intensity. Indeed, thermal imaging is a teleosense that is in most respects like vision. This capacity is lacking in human thermal experiences.

It is important, nevertheless, to acknowledge that the thermal experiences at issue are exteroceptive. Some have held that such thermal experiences should be considered mere sensations. Matthen (forthcoming) subsumes thermal perception under touch and differentiates between two kinds of touch experiences: tactile sensations and haptic experiences. The former are taken to be private and subjective; the latter are experiences of properties of things outside the body. It is only when thermal sensations are supplemented by active pressure-touch sensations that haptic touch arises and we feel things to have thermal properties.[7] On the view that I am defending, by contrast, all thermal experiences have contents. But the content of thermal experiences caused by distal objects is not a thermal property of the distal object. If it is true that such thermal experience is exteroceptive, then its most plausible content is the intensity of the heat impinging on the body and the direction from which the heat comes.[8] The claim has independent plausibility. It is crucial that we are aware of the heat transferred to and from the body for the sake of the integrity of the body. But it is because our thermal experiences have this content that we can also navigate to (or away from) a thermal source. We simply follow the direction in which the thermal experiences, and hence the heat, increases (or decreases) in intensity. Indeed, if thermal experiences did not inform us of the intensity of the thermal stimulation of the skin from outside it, we would not be able to locate its source. But it does not follow from this that the content of those thermal experiences includes the location of the thermal source. They merely represent the direction of the heat transferred to the body and its intensity.[9]

7. Matthen does not say what these thermal properties are, or, at least, he does not say what hotness and coldness are. As I argue in §5, it is hard to understand what these properties are without relating them to the transfer of heat to and from the skin in such a way that prioritizes the representation of the transfer of heat.

8. This view is consistent with both standard causal co-variation and teleological accounts of the representational contents of experiences. See, for instance, Dretske (1995) and Tye (1995). It is also consistent with the contrasting phenomenal intentionality approach. It differs from a template approach to touch, however, according to which bodily awareness of the thermal properties of the body acts as a template for the representation of the thermal properties of something else. The template approach owes us an account of what such thermal properties of the body are, which I maintain remains unclear. The temperature of the body is most often cited. But our thermal experiences of coldness and hotness do not easily map onto the temperature of the body (see §5). So, it is more plausible to think that sensations of hotness represent the heat transferred to the body, which they do map onto.

9. Compare this with following footsteps in the snow. We do not see the object that makes the footsteps, but we are still able to navigate to it by following the footsteps.

So, human thermal perception is not distal in either of the conceivable ways in which it could be. What is thermally perceived in Fulkerson's example are not the thermal properties of a distal object but rather the heat that is transferred to the body. There is also reason to think that what is thermally perceived by means of an implement or tool is the heat transferred to a part of the body. After all, when a metal rod transfers the heat from a hot object, it transfers it to the hand holding the rod. But more is required to substantiate the claim, and this issue is addressed in the next section.

That we do not experience the thermal properties of distal objects but, instead, heat that is transferred to the skin indicates that thermal perception does not satisfy the CP. It is a proximal sense because it detects proximal stimuli. Proximal senses and contact senses are, therefore, not the same. A contact sense is a proximal sense, but a proximal sense need not be a contact sense. If touch were merely a contact sense, it would be a proximal sense. Thermal perception caused by the heat transferred from a distal object is realized by a proximal sense that is not a contact sense because there is no contact with an object. Given that thermal perception is a proximal sense, whereas touch is a connection sense, thermal perception and touch are different types of senses. If thermal perception and touch are different types of senses, then token instances of thermal perception and touch should be instances of the operation of different token senses.

So far, I have challenged some of the arguments that are used to classify thermal perception as a kind of touch. If I am right about the distinction between thermal perception and touch, then that distinction should be captured by a specific individuation condition. So, what exactly is the individuation condition for distinguishing the two senses in operation here? Much work has recently been done on the individuation of the senses.[10] I take sensory modalities to be individuated in two ways: first, and least controversially, as distinct ways of perceiving a common feature (e.g., seeing and touching shapes), and, second, as distinct ways of perceiving a distinct feature. I take thermal perception to be distinct from touch because it detects a distinct feature in a distinct way. It detects the transfer of heat by means of distinct receptors in the skin that can be employed independently of other sensory receptors.[11]

With the thermal experiences that we have when we touch things, thermal perception is related more closely to the sense of touch. Nevertheless, I maintain that the view of thermal experiences caused by distal objects just defended has a significant bearing on how we should understand the thermal experiences caused by proximal objects and contrasts especially with those views that start out from a consideration of the thermal experiences caused by proximal things.

4. Proximal Thermal Perception

Thermal experiences are distinctive among perceptual experiences in so far as they can be caused by different kinds of physical stimuli. Whereas visual, auditory, and olfactory experiences are each enabled by one characteristic kind of stimulus, thermal experiences are enabled by two different kinds of physical stimulation: radiant energy and kinetic energy. For this reason, thermal experiences can be caused by both distal and proximal objects.

Thermal experiences caused by distal objects tend to be caused by thermal radiation. Thermal radiation, or radiant heat, of the sort to which humans are sensitive is electromagnetic radiation ranging from the infrared to the near ultraviolet part of the spectrum. It is called "thermal radiation" or "radiant heat," because the radiation is caused by the thermal state of the matter of the distal object. Radiant heat is emitted from an object as a consequence of electron oscillations or transitions between the orbits of electrons caused by the temperature of the object. When this radiation arrives at our skin, it is absorbed,

10. For relevant papers, see those in Macpherson (2011) and Matthen, Biggs, and Stokes (2014).

11. I take thermal receptors to be distinct kinds of receptors because they detect a distinct kind of feature: heat. Distinct kinds of visual receptors can be classed together and so can distinct kinds of tactual receptors, because they each detect distinct kinds of features.

increasing the kinetic energy of the molecules of the skin and thus its temperature. Hence, the kinetic energy that was transformed into radiation and emitted by the distal object is absorbed and transformed back into kinetic energy in the skin. It is thus that heat can be transferred over distance.

Thermal experiences caused by proximal objects are caused by the conduction of kinetic energy. The temperature of an object is determined by the average kinetic energy of the object's molecules. When things increase in temperature, their constituent molecules increase in motion. When objects touch, the object that has the greater temperature transfers its kinetic energy to the object that has a lower temperature, increasing the motion of the latter's molecules and, thereby, its temperature. When that object is a human body, the skin heats up as a result of its molecules becoming more energetic. It is thus that heat can be transmitted from one object to another with which it is in contact.

Despite the different means by which heat is transferred, it is important to emphasize that heat is transferred in both cases. It is for this reason that individual thermal receptors generally respond in the same way to radiant heat and heat conduction.[12] Indeed, thermal experiences can have identical phenomenal characters when they are caused by distal and proximal things. If thermal experiences caused in these different ways can be qualitatively identical, and so identical with respect to their phenomenal contents, and if the phenomenal contents of thermal experiences caused by distal objects is the heat transferred to the body, the phenomenal contents of the thermal experiences caused by proximal objects is the same: the heat transferred to the body.

Furthermore, it is plausible that if thermal experiences have the same character and phenomenal content then they are realized by the same sensory modality. If thermal perception can be distinguished from touch when thermal perception is enabled by radiant heat, why is it harder to accept that thermal perception is distinct from touch when it is enabled by conduction?

The main reason given for why pressure perception and thermal perception should be subsumed under a single sensory modality is that the thermal properties of things—their hotness or coldness—seem to be perceived by touching those things in the same way as the tactual properties of roughness, smoothness, hardness and softness are perceived. Fulkerson (2015, 3) says that "when we touch the bath water, we are attempting to determine the thermal state *of the water* … we feel its temperature, and then decide whether the water is too hot … Our experience is, it seems, about the state of the water" (his italics). I do not disagree that we are attempting to find out about the thermal state of the water. I disagree that we do this by feeling its temperature, if that means that the thermal experiences we have represent the temperature of the water.[13] Fulkerson proposes that thermal experiences can play multiple roles when thermal systems operate in conjunction with different tactual systems. They can directly inform us of the thermal state of the body; they can inform us of the thermal state of other things in conjunction with other tactual sensory systems; and they can inform us when thermal stimuli are a danger to us.[14] In my view, all these roles can be filled because the content of thermal experiences is

12. Hot and cold thermal receptors, which underlie experiences of hotness and coldness, are not evenly distributed around the body, as Akins (1996) notes. This provides support for her view that thermal experiences are selfish. Nevertheless, their distribution is a function of how important it is to detect the transfer of heat at different locations around the body, supporting the heat exchange view of thermal perception. Heat and cold receptors also have different patterns of activation. Interestingly, the pattern of activity of cold receptors also provides support for the heat exchange model. Cold receptors increase in activity as heat is lost but then decrease in activity. This makes no sense if thermal perception tracks the temperature of the body. It does, however, make sense if thermal perception tracks heat loss, because less heat will be lost once the skin has cooled to the temperature of a cold object that is touched.

13. For more on why I say this, see the next section.

14. Fulkerson (2014, 58) also claims that thermal perception is most accurate when we touch objects quickly and briefly because of adaptation effects. In my view, extended thermal perception can accurately inform us of the way in which heat is transferred by conduction. An object will seem to feel hot or cold when first touched and subsequently less so because the heat transferred

the heat that is transferred to or from the skin. If thermal experiences had such contents, we could come to know the thermal state of the body, the thermal properties of other things and when thermal stimuli are approaching a dangerous level of intensity. According to this line of reasoning, we do not perceptually experience the thermal properties of things in the same way as we perceptually experience their tactual properties. We feel the heat that is transmitted to the hand. Indeed, if too much heat is transferred to the hand, we will quickly remove the hand from the water.

Thermal perception mediated by conduction does not connect us to the thermal properties of things in the way that touch connects us to the tactual properties of things. It is true that making contact with an object puts us in a position to feel the heat that is transmitted to the body by conduction. But we do not then feel the heat by means of the sense of touch but rather by means of thermal perception. Although we typically have thermal experiences when we touch things, tactual perception and thermal perception can be separated.[15] Suppose that we are wearing insulated gloves to pick up an object. We would be able to feel the tactual properties of the object but would not detect any thermal stimuli.

The experiences we have when we touch hot objects (without gloves on) are consistent with feeling the texture and solidity of the objects and the heat that is transferred to the skin. Indeed, that we seem to feel the thermal properties of objects is how matters would seem if we detected the heat transferred to the part of the body in contact with an object when we touch it. When we make contact with the surface of an object, and its texture and solidity is detected by touch, the transfer of heat to the skin is enabled by the contact with the object. The heat that is transmitted to the body that is detected by thermal experiences is roughly equivalent to the heat that is transferred from the object. It can thereby appear that the content of our thermal experiences is the heat that is transferred from what is touched. Given that the contents of our thermal experiences are roughly equivalent to features related to the objects we touch, it can appear as if thermal properties of things are perceived.

This reveals another significant difference between visual and tactual experiences, on the one hand, and thermal experiences, on the other. Unlike our experiences of the color or texture of an object, which typically ground the perceptual beliefs we have about an object's color or texture, the beliefs we have about the hotness of an object are not grounded in experiences of the hotness of an object. Indeed, if the present line of argument is correct, the dependence holds in the opposite direction. Given that we believe that things are hot or cold, it is the beliefs we have about the hotness or coldness of things that help to sustain the view that we experience the hotness or coldness of objects. If this is right, we should accept the surprising, and not insignificant, conclusion that hotness and coldness are not sensible properties of things.[16]

Granted that it is generally held that we seem to perceptually experience the thermal properties of things, this might suggest an error theory. Both the thermal experiences we have when we touch things and the beliefs that we form on their basis would be in error. If our thermal experiences seem to be of the thermal properties of the objects we touch, then those experiences would be in error if they are not of such properties. And if the content of the beliefs we have about the thermal properties of things are based on the apparent content of our thermal experiences, then they too would be in error.

However, an error theory is not the only response. If thermal experiences detect the transfer of heat, they are generally accurate. And

to or from the skin brings about thermal equilibrium and reduces the transfer of heat, which is what we experience.

15. Although contact is the feature shared by both tactual perception and thermal perception here, the necessity and sufficiency of contact is not. Contact is necessary for touch but not sufficient and contact is necessary for only one means of realizing thermal perception.

16. Perhaps the claim is not so surprising. Whereas it would be hard to deny that distal features—colors and sounds—are sensibles and tactual features are sensible properties of things because they are not merely felt by touch but also perceived by vision, the contents of thermal experiences enabled by contact are not corroborated in another way.

we do come to believe that things are hot or cold by means of our thermal experiences. For it to be possible to come to believe that an object has a thermal property on the basis of thermal experiences that have a different content, it must be the case that the content of thermal experiences is, nevertheless, relevantly related to the thermal properties of things. Experiencing the heat transferred to the skin when we touch something hot clearly justifies our thinking that something has the property of hotness. It will do so if the hotness of things is constitutively related to the heat transmitted to the skin, such that perceptually experiencing the heat transmitted to the skin justifies the belief that an object is hot.

One might take the hotness and coldness of things to be response-dependent properties, properties that things have in virtue of enabling an experiential response in normal perceivers. Something is hot just in case it enables heat sensations in normal observers. Something is cold just in case it enables cold sensations in normal observers. I assume that more than this is required for a full explanation. An explanation is required in scientific terms of how thermal experiences relate to thermal features. Such experiences inform us of the transfer of heat to or from the skin. Heat sensations inform us of the heat transferred to the skin. Cold sensations inform us of the heat transferred from the skin. What remains is to provide an account of the thermal properties of things which depend on the heat transferred to or from the skin, and the attribution of which would thus be justified if our thermal experiences were of the heat that is transferred to or from the skin and a reason to think that the thermal experiences that we have when we touch things are not of those thermal properties of things.

5. Thermal Experiences and Thermal Properties

It is plausible to think that there should be a perceptual relationship between our thermal experiences and the thermal properties of the things we touch. After all, it is plausible to think that it is the thermal properties of those things that cause our thermal experiences when we touch them. The natural property with which the thermal properties of things —their hotness and coldness—are most frequently identified is the temperature of things. Something is cold if it has a low temperature and hot if it has a high temperature. Having a determinate temperature is an intrinsic property of something, a property that something has independently of its relationship with anything else. On such an identification, coldness and hotness would be intrinsic properties of things. As already noted, temperature can be given a further naturalistic explanation: it is the measure of the average thermal energy of a body, which can, in turn, be explained as the average kinetic energy of the molecules constituting the object. A body of matter being cold or hot would, therefore, be naturalistically explained by the molecular constitution of the matter having either a low or high average kinetic energy, respectively.

However, the above view of the thermal properties of things we touch is at odds with our thermal experiences. Temperature is a property whose values constitute a single dimension extending from low temperature to high temperature. Hotness and coldness are associated with distinct kinds of thermal experiences. Indeed, each of these thermal features constitute distinct dimensions that extend from low intensity to high intensity. This suggests not only that thermal experiences do not represent the temperature of other things, but also that thermal experiences do not represent body temperature; hence, it forestalls a template approach to thermal perception.

There are other reasons to doubt that hotness and coldness are equivalent to intrinsic thermal properties of things, such as their temperatures. Something feels hot or cold to a normal perceiver not merely because it is at a certain temperature but because it is at a certain temperature relative to a normal perceiver. The skin of a normal perceiver is approximately 30–36ºC. Something seems to feel hot only if its temperature is higher than 36ºC. Something seems to feel cold only if its temperature is lower than 30ºC. Given what enables thermal experiences, there is more reason to identify the coldness or hotness of something with a relational property: the lower or higher temperature, respectively, of something relative to the temperature of a normal perceiver. Coldness, and degrees of coldness, might then be identified with a dimension that starts at the temperature of a normal perceiver and increases as the temperature of a thing falls with respect to the perceiver. Hotness, and degrees of hotness, might be identified with a dimension that starts at the temperature of a normal perceiver and increases as the temperature of a thing rises with respect to the perceiver. The two dimensions are related in so far as they have the same point of reference: the temperature of a normal perceiver. Given the explanation of temperature in terms of molecular motion, things would be hot or cold if and only if they have a greater or lesser molecular motion, respectively, than the skin of a normal perceiver.[17]

A difference in temperature between an object that is cold or hot and a normal perceiver is significant for another reason. All things being equal, heat will be transferred from an object at a greater temperature to an object at a lower temperature. For an object to seem to be felt as hot or cold, it is necessary for heat to be exchanged between the object and the skin of a normal perceiver or vice versa. But this must also be the case for an object to be hot or cold. An object is hot only if heat is transferred to a normal perceiver in contact with it and is cold only if heat is transferred from a normal perceiver in contact with it. Hence, it starts to become clearer why an object can be hot or cold only in relation to a normal perceiver and, moreover, why the hotness or coldness of an object is known by detecting the heat transferred to or from the skin of a normal perceiver.

There is, however, still a difficulty with the identification of coldness and hotness with the temperature of something relative to the temperature of a normal perceiver. Consider an everyday thermal phenomenon. Objects at room temperature often have a lower temperature than the skin. Therefore, heat is transferred from the skin of a normal perceiver to the objects at room temperature when they are touched. It is a commonly observed fact that at the same room temperature (say about 20°C), some objects seem to feel cold whereas other objects do not. A metal object will seem to feel cold at room temperature when a glass object seems to feel merely cool, and an object made of acrylic seems to feel neither cold nor cool. Given that the objects are all at the same room temperature, were the coldness of an object its temperature relative to a normal perceiver, it would follow that the objects have the same degree of coldness. Yet, we typically think of the metal object as feeling colder than the other objects.

The difference in how objects seem to feel at room temperature can be explained by differences in the thermal properties of their material constituents other than their temperatures.[18] Specifically, appearances can be explained by the differences in the thermal conductivity and heat capacity of the materials that constitute the objects. Thermal conductivity is an object's capacity to transfer heat. If an object has a high thermal conductivity, it has a greater capacity to transfer heat. Heat capacity is an object's ability to store heat. A greater heat capacity allows an object to continue to exchange thermal energy with another object for longer because of the thermal energy it has stored or is able to store. The way in which an object seems to feel at room temperature when we touch it is standardly understood by reference to a function of its thermal conductivity and heat capacity (more precisely, the square root of their product). This is known as a material's contact coefficient. Metallic objects seem colder than objects constituted by other types of materials because they have higher contact coefficients. They are, therefore, better able to transfer heat from objects with which they are in contact that are at a higher temperature. Objects that are constituted by materials with lower contact coefficients are less able to transfer heat from objects with which they are in contact that are at a higher temperature.

Should we think that objects that appear colder at the same temperature merely appear to be colder? If such a distinction between appearance and reality can be drawn, then something could be cold without feeling so. Even if coldness is not a sensible property, it is hard

17. Again, such an approach would be inconsistent with a template approach.

18. For a useful discussion of the thermal properties of objects that bear on the transfer of heat, see Ho (2018).

to deny that we draw a connection between the experiences of coldness that something generates in a normal perceiver and its coldness. We think of things as cold or hot only because they cause thermal experiences of two broad kinds: experiences of coldness and hotness. But if this is the case, then coldness and hotness must be identified with more than the temperature of something relative to a normal perceiver. Coldness and hotness must be identified with a complex property constituted by the combination of thermal properties that contribute to the transfer of heat.

Accordingly, coldness is best understood not merely as the lower temperature of something relative to a normal perceiver. The coldness of an object must be understood as a complex property that is constituted by both its lower temperature relative to the skin temperature of a normal perceiver and the magnitude of the contact coefficient of the material that constitutes the object. According to this way of thinking, coldness can be understood as follows:

> **Coldness (C)**: The lower temperature of an object relative to the skin temperature of a normal perceiver in conjunction with the magnitude of the object's contact coefficient.

Something that has a lower temperature than the skin temperature of a normal perceiver but has a low contact coefficient would not feel cold. But then it would not be cold. By contrast, something that has a lower temperature than the skin temperature of a normal perceiver and has a high contact coefficient would feel cold. But then it would also be cold.

Significantly, however, for present purposes, C depends on the transfer of heat from a normal perceiver with whom an object is in contact. Relative temperature, thermal conductivity, and heat capacity, taken jointly, constitute C through their contribution to the transfer of heat from a normal perceiver. C is a property that can be attributed to objects, but this property is constituted by its complex capacity to transfer heat from a normal perceiver. Therefore, it cannot be attributed independently of the heat that can be transferred from a normal perceiver. Therefore, when an object in contact with the skin generates a cold sensation and the heat transferred from the skin is detected, we can determine that the object is cold.

Similar thermal phenomena are manifested in the case of hotness. Consider the way in which some objects seem to feel hotter than other objects at the same temperature. Drinking mugs are usually made of ceramic. But they are sometimes made of glass and even metal. Suppose that you pour liquid of the same temperature into a token of each type of mug. They will all seem to feel hot to the touch. But there will also be a noticeable difference in the way each mug appears. The metal mug will seem to feel hotter than the ceramic mug, as will the glass mug. The metal mug will seem to feel hotter because it has a greater contact coefficient than the ceramic mug. When I pick up my metal mug, I will have a more intense experience of heat, because my metal mug has greater thermal conductivity than my ceramic mug. The greater thermal conductivity of the metal causes greater transfer of the heat of the liquid to my hand. The glass mug will also seem to feel hotter than the ceramic mug. Although the thermal conductivity of my glass mug is less than my ceramic mug, my glass mug has less heat capacity than my ceramic mug, which prevents it from holding as much of the heat that is transferred from the liquid in the mug to the mug than is the case with the ceramic mug, thereby increasing the amount of heat that is transferred to my hand. Hence, an equivalent way of understanding hotness is as follows:

> **Hotness (H):** The higher temperature of an object relative to the skin temperature of a normal perceiver in conjunction with the magnitude of the object's contact coefficient.

H depends on the transfer of heat to a normal perceiver with whom an object is in contact. Relative temperature, thermal conductivity, and heat capacity, taken jointly, constitute H through their contribution to the heat transferred to a normal perceiver. H is a property that can be attributed to objects, but this property is constituted by its complex capacity to transfer heat to a normal perceiver. Given that H cannot be understood independently of the heat that can be transferred to a normal perceiver, it should be clear how we can determine the hotness of an object by perceptually experiencing the heat that is transferred to the skin when contact is made with the object.

C and H provide proposals for the coldness and hotness of an object that is touched and thus also for the contents of our beliefs about the coldness or hotness of such objects. I claim that these contents differ from the contents of our thermal experiences. Such experiences tell us when heat is transferred to or from the skin. It should now be clear that something is cold or hot only if it has properties that enable it to transfer heat from or to a normal perceiver, respectively. Hence, we can know whether an object is cold or hot from the thermal experiences we have when we make contact with objects because such experiences tell us that the object that is touched has the capacity to transfer heat in a particular direction.

According to the view set out here, the coldness or hotness of an object is not the kind of property that can be directly detected by means of perceptual experiences. Hotness and coldness can be detected only by discerning the heat that is transferred from or to the skin of a normal perceiver. If it is maintained that hotness and coldness, as defined here, can be perceptually experienced in feeling something to be hot or cold, because what is detected by such experiences is the capacity to transfer heat to or from the skin, it can be pointed out that we could perceive such capacities only if we perceived their realization by perceiving the transfer of heat to or from the skin.

6. Concluding Remarks

We perceive the colors of things and the sounds that they make by means of the physical stimuli that are transmitted to us. But we do not perceptually experience those physical stimuli. There is a good reason for this: we need to be aware of what causes the stimuli; we do not need to be aware of the stimuli themselves. In this paper, I have argued that there is an exception to this general rule. In the case of thermal perception, we detect the thermal stimuli that are transferred to or from the skin. We need this information to help us maintain the body at an appropriate thermal equilibrium.

Nevertheless, in detecting the heat that is transferred from or to the objects that we touch, we can determine the hotness or coldness of those objects, because their hotness or coldness is constituted by the complex capacities the objects have to enable the transfer of heat to or from the skin of a normal perceiver. Perceptually experiencing the heat that is transferred to or from the skin is easily mistaken for perceptually experiencing the hotness or the coldness of an object, especially because, in experiencing the transfer of heat, we come to know the capacity of the object we touch to transfer heat to or from a normal perceiver with which it is in contact and thereby its thermal properties.

References

Akins, K. (1999). "Of sensory systems and the 'aboutness' of mental states," *Journal of Philosophy*, 93:7, 337–372. https://doi.org/10.2307/2941125

Drestke, F. (1995). *Naturalizing the Mind*, Cambridge, MA: MIT Press.

Gray, R. (2013). "What do our experiences of heat and cold represent?" *Philosophical Studies*, 166: S1, 131–151. https://doi.org/10.1007/s11098-012-0083-5

Fulkerson, M. (2012). "Touch without touching," *Philosophers' Imprint*, 12:5, 1–15. http://hdl.handle.net/2027/spo.3521354.0012.005

Fulkerson, M. (2014). *The First Sense*, Cambridge, MA: MIT Press.

Fulkerson, M. (2015). "Rethinking the senses and their interactions: The case for sensory pluralism," *Frontiers in Psychology*, 5, 1–14. https://doi.org/10.3389/fpsyg.2014.01426

Ho, H. (2018). "Material recognition based on thermal cues: Mechanisms and applications," *Temperature*, 5:1, 36–55. https://doi.org/10.1080/23328940.2017.1372042

Macpherson, F. (ed.) (2011). *The Senses: Classic and Contemporary Perspectives*, Oxford: Oxford University Press.

Martin, M. G. F. (1992). "Sight and touch," in T. Crane (ed.) *The Contents of Experience*, 196–215, New York: Cambridge University Press.

Matthen, M., Biggs, S. & Stokes, D. (eds) (2014). *Perception and its Modalities*, Oxford: Oxford University Press.

Matthen, M. (2015). "Individuating the senses," in M. Matthen (ed.) *Oxford Handbook of the Philosophy of Perception*, 567–586, Oxford: Oxford University Press.

Matthen, M. (forthcoming). "The dual structure of touch: the body v. peripersonal space'," in F. de Vignemont (ed.) *The World at our Fingertips*, Oxford: Oxford University Press.

O'Shaughnessy, B. (1989). "The sense of touch," *Australasian Journal of Philosophy*, 67:1, 37–58. https://doi.org/10.1080/00048408912343671

Ratcliffe, M. (2012). "What is touch?" *Australasian Journal of Philosophy*, 90:3, 413–432. https://doi.org/10.1080/00048402.2011.598173

Scott, M. (2001). "Tactual perception," *Australasian Journal of Philosophy*, 79:2, 149–160. https://doi.org/10.1080/713931200

Tye, M. (1995). *Ten Problems of Consciousness*, Cambridge, MA: MIT Press.

de Vignemont, F. & Massin, O. (2015). "Touch," in M. Matthen (ed.) *Oxford Handbook of the Philosophy of Perception*, Oxford: Oxford University Press.