



Making Sense of Temperature in Early Psychophysics

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How do human bodies sense the hotness and coldness of things? Not like a thermometer does, answers Ernst Heinrich Weber in *Tastsinn und Gemeingefühl (Sense of Touch and Common Feeling)* (1846). A thermometer registers the “heat of the mercury” at any given moment, while the human body instead registers changes from its “zero point” (the temperature of the body or skin) as positive and negative magnitudes.

Sense of Touch and Common Feeling was originally published as part of a series of articles on physiological topics edited by Rudolph Wagner. The text expands considerably upon Weber’s earlier Latin treatise on the tactile sense, *De Tactu* (1834), and is, generally speaking, more theoretically ambitious than the earlier work. While the first half of *Sense of Touch* presents research on the effects of weight, pressure, and temperature on the nervous system of the skin, the second half of the text interrogates the connection between mind and body in the context of *coanaesthesia* (i.e., generalized feelings that cannot be attributed primarily to an external source such as pain, hunger, etc.).¹ It would be hard to overstate the importance of Weber’s 1846 text for the subsequent development of the disciplines of experimental psychology and sensory physiology (Ross & Murray, 1996). Indeed, Gustav Fechner referred to his former mentor Weber as the “father of psychophysics” (1860, p. v), stating that in the “classic investigations” of *Sense of Touch*, Weber had laid out the basic categories of psychophysical inquiry. Among other things, *Sense of Touch* describes Weber’s influential two-point discrimination test and provides the fullest description of what came to be known as Weber’s Law.² It also elaborates considerably on Weber’s investigations, first described in *De Tactu*, of the human body’s response to hot and cold stimuli.

¹ On the history of medical theories of coanaesthesia, see Daniel Heller-Roazen (2007), particularly pages 237–251. Coanaesthesia, as Heller-Roazen summarizes it, was in all its forms “the name of both the solution and the difficulty: the cipher of that sense by which animate beings dimly feel they are alive” (p. 250).

² That is, as the level of a given stimulus varies, the smallest change one can perceive depends on the foregoing/baseline level of stimulus and that the ratio of these two quantities (“just noticeable difference”: baseline stimulus) is a constant. Weber described this relationship in the context of his experiments on sense of pressure, in which weights were used as stimulus. The name for this relationship between stimulus and response—Weber’s Law—was given by Fechner. (He went on to suggest a revised, logarithmic relationship, calling this revision the Fechner-Weber Law.)

In *Sense of Touch*, the faculty is further subdivided into three kinds of awareness: sense of location on the body (*Ortsinn*), sense of pressure (*Drucksinn*), and sense of temperature (*Temperatursinn*). Short passages summarize experiments in each of these domains. In addition to two-point discrimination tests, a range of stimuli of varying pressure and temperature were applied to different parts of the body. Weber explains to the reader that sense of touch arises through the presence of peripheral nerves in the skin and that these nerves are distributed unequally along the skin's surface. Thus, for each of the three subsenses of location, pressure, and temperature, Weber creates a kind of empirical atlas in which the effects of stimuli on different parts of the skin's surface are noted.

The section on "sense of temperature" (*Temperatursinn*) begins with introductory remarks in which the human body is compared to a thermometer (as described above). Because we have a source of heat (*Wärmequelle*) within us, Weber explains, hot and cold are felt as positive and negative magnitudes from this fluctuating zero point. Similarly, in *De Tactu* (1834), he states that hot and cold are felt as "positive and negative numbers" (p. 170). But Weber's introductory remarks on "temperature sense" also mark an important shift from his explanation in *De Tactu* of the mechanism by which we sense heat. In *De Tactu*, Weber lays great emphasis on the fact that our assessment of temperature is an act of "estimation." He describes a two-step process: first, the touch-organ (*organo tactus*) perceives heat or cold. Then, using this information, we judge the temperature of objects. This judgment is an act of estimation, not of perception, Weber stresses.³ Twelve years later, in *Sense of Touch*, Weber omits the concept of estimation, instead claiming that the body senses temperature directly.

Weber outlines experiments that have allowed him to quantify and map the human body's sensitivity to temperature. First he presents a series of experiments in which a hand was placed in water of varying temperature.⁴ The resulting sensations of hotness and coldness and their alterations over time are described. For example:

If I dip my hand into water with a temperature of 12½°C for one minute, and then into water of 18°C, I have a feeling of warmth in the latter for several seconds, but after this a feeling of cold sets in that lasts as long as the hand is submerged. (Weber, 1846, p. 551)⁵

The frequent failures of the human body to perceive temperature accurately are also addressed. Why do we often misperceive hot and cold objects? Why do we often "not perceive temperature correctly"? (Weber, 1846, p. 551, emphasis added). For these failures, Weber provides two explanations. The first is that we perceive hot and cold differently depending on how well a given object conducts heat. Thus a cold wooden stick seems less cold to us than a metal rod of the same temperature. The second is that the heat of our skin is variable, because of changes in blood flow, for instance, or prolonged exposure

³ "Aestimari a nobis temperiem dico, non percipi" (Weber, 1834, p. 113).

⁴ Weber generally gives temperature measurements in both degrees Celsius and Réaumur, though he sometimes presents only one or the other.

⁵ All translations from *Sense of Touch and Common Feeling* are my own. Weber moves freely between first-person narration and a more impersonal third-person voice in descriptions of his experimental results.

to extreme temperature. Nevertheless, Weber notes that, among other findings, most individuals seem to be able to perceive a temperature difference as small as $2/5^\circ$ Réaumur.⁶

In his final remarks on temperature sense, Weber describes the variable sensitivity of different parts of the skin to temperature. Hot and cold seem to make a "stronger impression" (Weber, 1846, p. 552) on the left hand than on the right. He speculates that this might be caused by a thinner epidermis on the left side. Weber presents a detailed atlas (in words) of the body in terms of its variable temperature sensitivity. Two experimental apparatuses are described. In the first of these, two vials were filled with oil and fitted with caps that held a thermometer in place. These vials were warmed or cooled in water, wiped off, and then placed on two different parts of the skin. In the second set of experiments, a large metal key was heated and cooled; the cylindrical end of the key was then placed in contact with two locations on the skin, switching back and forth between the two locations repeatedly. In order to heat or cool the key, Weber used two methods: in some cases, the key was dipped in a mercury bath of known temperature; in others, the key was laid on a "very cold stone slab" in front of a window where the temperature was displayed until the key "took on the temperature of the slab" (Weber, 1846, pp. 554–555). In this way, Weber determines, for instance, that

the sensation of change in temperature is much duller on the tip of the nose than on the side of the tip of the nose; sensitivity increases quite a bit on the nostril, and is greatest on the lower margin of the outer part of the nostril. (1846, p. 555)

Yet, reflecting on the legacy of psychophysical research some 60 years later, Ernst Cassirer points out in *Substance and Function* that "it is a long way from the immediate sensation of heat to the exact concept to temperature" (1910/2003, p. 142). In a section devoted to critique of the foundational assumptions of psychophysics, he argues that "the indefinite stronger and weaker of impression offers no foothold for gaining fixed numerical values" (p. 142). In his critique of the slippage between concepts of heat and temperature, Cassirer claims that in experiments such as Weber's, sensations as such were not measured, but "only the *objects* to which we relate them" (1910/2003, p. 142). Even if sensation were indeed measurable by such mediation, Cassirer goes on, this tells us little about perception, because

even granting this assumption, it is clear that the physicist . . . has nothing to do with sensations of warmth or contact, but only with temperature and pressure. None of these concepts however can be understood as a simple copy of the facts of perception. (1910/2003, pp. 141–142)

The underlying assumption of mediation between feelings of hot and cold and thermometric quantities may not be justified, or even if it could be, does not provide real insight into perceptual experience. Weber's description of temperature "estimation" in *De Tactu* allows the separation between the conceptual realms of heat and temperature, between perception and estimation; the more radical "temperature sense" in *Sense of Touch*, however, elides any human experience of heat that does not concern the "positive and negative numbers" of a temperature scale.

⁶ 1° Réaumur = 1.25° Celsius.

Weber's sensory physiological experiments in *Sense of Touch* and Cassirer's critique of 19th-century investigations of the *qualia* in *Structure and Function* share a central figure: the thermometer. While Weber initially insists that human sense of temperature operates differently than a thermometer does, he nonetheless necessarily uses the thermometer as the standard against which the human ability to sense temperature is measured (Hess, 2000). Sensations of hot and cold are assumed to exist along a theoretical scale that can be aligned with a thermometric scale (in both *De Tactu* and *Sense of Touch*), inaugurating a psychophysical program that aligns "objectively" measured stimuli and "subjective" sense. For good reason, then, Cassirer selects the thermometer to stand in for a larger critique of psychophysics. A glass tube with etched markings in which the volume of mercury (or alcohol, or water, in the long history of thermometer production and calibration [Chang, 2004]) expands to indicate rising temperature and contracts as temperature falls—what does the process of expansion and contraction in this tube necessarily have to do with other phenomena of heat and their measurability? Cassirer asks. Cassirer insists on the utter incommensurability of a length of mercury with the "indefinite stronger and weaker" of feeling hot or cold; as far as he is concerned, since the Weberian notion of *Temperatursinn* begins and ends with the thermometer, it makes no sense at all.

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