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Review

On the Multisensory Experience of Humidity: A Multidisciplinary and Multicultural Perspective

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Abstract

In this narrative historical review, we take a critical look at the multisensory experience of atmospheric moisture. While not sensed directly (rather, at its most basic, it is a touch blend), this sensation, which can be either positive or negatively valenced (in part, depending on whether we are in charge of the experience), reflects an inference about the environmental conditions as potentially assessed at the skin surface. The perception of humidity has been largely ignored by the long history of research on tactile psychophysics and instead appears only recently in the writings of environmental psychologists. Nevertheless, the perception of humidity is likely to become a growing environmental issue (e.g., in the era of global climate change). We look at the multisensory influences on the perception of humidity, a crucial component of thermal comfort, and possible individual, group, and cultural differences.

Keywords

touch blend, wetness, atmosphere, multisensory, crossmodal

1. Introduction

Atmospheric moisture is an invisible yet pervasive condition that shapes environments, ecologies, and people's everyday lived experience. Its importance has been recognised in many disciplinary fields. For instance, a simple search

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for the terms 'humidity' AND 'thermal comfort' on the Web of Science yields a substantial number of papers: 5,327 to be exact. These papers are primarily categorised under the following fields: Construction Building Technology (34%), Civil Engineering (24%), Energy and Fuels (19.7%) and Environmental Engineering (14.2%). Additional papers are spread across multiple disciplinary fields such as Architecture, Physiology, Physics, Agricultural Engineering, and Materials Science, particularly textiles. In fact, there can be little doubting that humidity is a key component of thermal comfort in the built environment (Just *et al.*, 2019). However, humidity is not a topic that has attracted all that much interest from academic researchers within the social sciences and humanities, and certainly not from those psychophysicists who are interested in the sense of touch (see Gallace and Spence, 2014; McGlone and Spence, 2010; Nafe, 1927, 1934; Schiller, 1956).[1] Instead, discussion of the negative impact of extremes of humidity seemingly first appeared in the context of environmental psychology, specifically in relation to issues of thermal comfort in the built environment (Liu *et al.*, 2023).

In the context of rising ambient temperatures driven by anthropogenic activities, it is often air moisture levels, rather than temperature in-and-of-itself, that determine how heat is experienced, endured, and survived (Sobolewski *et al.*, 2021; Zhang *et al.*, 2023). High humidity amplifies heat stress, accelerates infrastructure decay, and reshapes everyday practices. Moreover, the Intergovernmental Panel on Climate Change (IPCC)'s Sixth Assessment Report (AR6) identifies near-surface atmospheric humidity as a key climate variable, noting increases of about 7% absolute humidity per 1°C since the 1970s, though unevenly distributed across regions. This means that around the world, regions and cities may experience conditions that are drier or else more humid. Humidity, then, matters and will matter all the more in the climate conditions to come. In terms of human health, Guarnieri *et al.* (2023) found that relative humidity (RH) contributes to the spread of infections and the worsening of respiratory conditions. High RH creates a damp environment that helps to promote the growth of harmful microorganisms such as bacteria (e.g., *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Enterobacter* and *Legionella*), as well as viruses such as influenza and adenovirus increase at RH below 50% and above 70%. Mites are absent below 50% RH in winter, while indoor fungi proliferate above 60% RH (Guarnieri *et al.*, 2023). Excessive RH enhances the release of formaldehyde, odours, and pollutants such as acrolein, while low RH encourages the formation of indoor ozone, irritating the respiratory system (Guarnieri *et al.*, 2023). Thermal-comfort guidelines, such as ASHRAE Standard 55,

[1] Although there is a very large body of research on humidity in the fields of chemistry, industrial processes, art conservation, etc.

generally recommend indoor RH levels between 30% and 60% for occupant comfort; beyond such range RH levels negatively impact mucociliary clearance, epithelial integrity, and conjunctival mucosa. Atmospheric RH influences pollution levels and pollen production, potentially worsening allergies and asthma. Long-term exposure to humidity has also been associated with increased cardiovascular disease hospitalisation (Klompmaker *et al.*, 2023).

While excessive humidity is often considered by commentators to be a negatively valenced atmospheric (or ambient) condition (e.g., Bett, 2025), there are, of course, particular situations in which it is positively valenced (e.g., in the steam room or sauna; see Valen, 2022).[2] The key feature that distinguishes the opposing valence associated with these different situations would appear to be the degree of control that the individual has (over the experience) and the comfortableness of the experience (Paciuk, 1990; Sakellaris *et al.*, 2019; Schweiker *et al.*, 2018).

Given global concerns about climate change (WHO, 2023), issues of thermal comfort/justice are likely to become increasingly salient (see Bett, 2025; Doherty and Clayton, 2011; Gibson, 2025; Mazzone, 2024).[3] As such, understanding the psychology of humidity perception, and determining how thermal comfort (including the experience of humidity) can be influenced and potentially modified by the use of simultaneously presented cues in other sensory modalities becomes all the more important. According to DeWeerdt (2018), as the world gets warmer, the heat index increases more than the air temperature. In other words, how hot it feels will increase more rapidly than the mercury in the thermometer rises.

Taken together, these threads highlight a striking imbalance: although humidity plays a decisive role in shaping thermal comfort, health, infrastructure and lived experience (an influence that will only intensify under climate change), it remains markedly underexamined within the social sciences and the psychology/psychophysics of human perception. What is missing is a fuller account of how humidity is sensed, interpreted and negotiated in everyday life, and how these perceptual processes interact with wider environmental, cultural, and technological contexts. Addressing this gap in the literature is essential if we are to understand not only how humidity is felt, but also how its

[2] Exposure to high humidity is sometimes used as a medical treatment, as in the case of humidified oxygen therapy or steam inhalation or nebulisation for colds, sinusitis, bronchitis and so on (Marcet, 1881; Rea *et al.*, 2010). More recently, prospective clinical evidence suggests that frequent sauna bathing may also reduce the risk of developing COPD (Kunutsor and Laukkanen, 2023), further supporting the therapeutic potential of controlled humid-heat exposure. Note that thermal treatments have also started to appear in the context of mental health treatments as well (e.g., Nord and Garfinkel, 2022).

[3] Visible steam has also started to play a role in various steam-based architectural installations (Nakaya, 1998; see also Böhme, 2013, 2019).

effects might be mediated, moderated, or even reconfigured in an increasingly warm and moisture-laden world.

These patterns point to an urgent need to better understand humidity as both a physical and a lived phenomenon. Accordingly, this review brings together research from the fields of environmental psychology, human physiology, the sciences of the built environment, and anthropology that touches directly or indirectly on humidity, in order to map what is known about its perception and experience, and to identify where conceptual and empirical advances are most needed. Such an integrated perspective is crucial as societies increasingly confront the embodied and infrastructural challenges posed by more frequent and intense humid heat.

1.1. Review Outline

In this narrative state-of-the-art historical review (see Ferrari, 2015; Furley and Goldschmied, 2021; Greenhalgh *et al.*, 2018, on the strengths of narrative reviews) on humidity in multisensory and crossmodal research, we synthesise findings from psychology, environmental physiology, and anthropology in order to examine how atmospheric moisture interacts with visual, tactile, olfactory, and thermal cues. We highlight the absence of humidity as a sensory dimension in current models of multisensory perception and propose new conceptual and methodological pathways integrating environmental and sensory humanities perspectives into a holistic multisensory view of humidity perception.

To organise this synthesis, the review is structured around a working conceptual framework with four interconnected components: (1) an inferential process, whereby humidity is never sensed directly but is rather inferred on the basis of converging multisensory signals; (2) hierarchical multisensory pathways, with thermotactile integration as the primary and best-established route, and olfactory, visual, auditory, and interoceptive channels contributing in secondary, context-dependent ways; (3) modulating factors, including prior experience, acclimatisation, cultural context, and individual differences, that shape how sensory signals are weighted; and (4) affective valence, whereby the same atmospheric conditions can be experienced as oppressive or pleasurable depending on degree of control and cultural context. This framework is summarised visually in Figure 1 in Section 4 and guides the structure of the review throughout.

2. On the Multisensory Perception of Humidity

At the outset, it is worth distinguishing two related but distinct constructs: atmospheric humidity and the perception of skin wetness. Atmospheric humidity refers to the amount of water vapour present in the surrounding air, standardly measured as RH, the metric used in built-environment research and underpinning international comfort standards such as ASHRAE 55 and ISO 7730. Absolute humidity, which expresses the total mass of water vapour per unit volume independent of temperature, is rarely employed in human perception research because it does not reflect the conditions experienced by the body: the skin's capacity to lose heat and moisture through evaporation depends on how close ambient air is to saturation, not on the raw quantity of water vapour it contains. The perception of skin wetness, by contrast, is a somatosensory experience arising from the integration of thermal and tactile signals at the skin surface. Although high ambient humidity can impair evaporative cooling and thereby promote sensations of skin dampness, the two constructs are not synonymous: a humid environment does not necessarily produce wetness perception, and wetness can be perceived in the absence of actual moisture. Crucially, even as an atmospheric measure, RH does not map straightforwardly onto subjective experience: the same RH value can be experienced very differently depending on temperature, air movement, clothing, activity level, and individual factors. It is precisely this gap between physical measurement and perceptual experience that the present review seeks to address.

2.1. Humidity as a Multisensory Touch Blend

According to Watanabe *et al.* (2025), while humans can undoubtedly sense environmental humidity, the mechanism underlying this ability remains unclear. One of the interesting questions here concerns how, exactly, humidity may be sensed (Filingeri and Havenith, 2015). If the skin is considered as the main organ responsible for humidity 'detection', then we might encounter a problem, as there are no dedicated 'wetness' detectors in the human skin (see Ackerley *et al.*, 2012). As such, the sensation of humidity, like that of wetness, likely reflects a 'touch blend' (Fan and Zhang, 2024; Liao *et al.*, 2018; Singhal *et al.*, 2024). Bentley (1900) famously first introduced the notion of touch blends in his studies of synthetic perception by showing that if one puts one's hands in thin latex gloves and then dips one hand in cold water, the other in warm water, only the cold hand will feel wet, despite the fact that neither hand actually is wet. What this simple demonstration powerfully shows is that wetness is a touch blend resulting from the combination of pressure and temperature.

Here it is interesting to note that there are several phenomenal properties that are relevant to the understanding of humidity perception. The sense of liquidity/solidity that Bentley (1900) mentions can be thought of as a material property (see also Sullivan, 1923). The perception of humidity and wetness would appear to be exteroceptive, relating more to atmospheric condition, whereas thermoreception is primarily an interoceptive sense (see Toussaint, Heinzle and Stephan, 2024).

One might ask the question of which kinds of receptor in the skin play a role in the context of humidity detection. A possible answer comes from neurophysiological studies. Human humidity perception has been shown to result from experience-dependent multisensory integration of cold-sensitive thermal afferents and mechanoreceptors, processed centrally in somatosensory cortices through Bayesian inference that seems to prioritise thermal over tactile inputs, with perception context-dependently modulated by whole-body thermal state and prior experience (see also Toussaint *et al.*, 2024). This entails that humidity perception relies on the integration of thermal and tactile inputs rather than the response of any kind of dedicated hygroreceptors (Filingeri and Havenith, 2015).

Psychophysically, human perception of RH conforms to Fechner's law, exhibiting nonlinear relationships between the physical RH stimulus and its perceived intensity (Li, 2005). This means that as RH increases, the perceived change in humidity decreases, so that differences at higher humidity levels are less noticeable than equivalent differences at lower levels. It is important to note that what is measured in such studies is perceived humidity, a form of subjective report, rather than RH itself, and these two constructs, though related, are not synonymous. Perceptual experience evolves from basic thermal sensations to more complex qualitative states such as feeling stifled, sticky, or dull (Uemae, Uemae and Kamijo, 2022). Although research using diverse methodologies has produced converging evidence, the field still lacks systematic study of individual differences and of the neuromolecular mechanisms involved, which remain only partially understood (Filingeri and Havenith, 2015). A limitation in this field seems to persist: framing the perception of humidity solely as a thermotactile process might be insufficient; additional sensory modalities, including olfactory, visual, and interoceptive cues, may also contribute to what is ultimately a multisensory experience. This is not merely a question of incompleteness. Framing humidity perception solely as a thermotactile process risks producing psychophysical models that are ecologically invalid, valid in the controlled chamber but poorly generalisable to the richly multisensory environments in which humidity is actually encountered.

2.2. *Crossmodal Influences on the Perception of Humidity*

Thermoception and/or thermal comfort (including the experience of humidity) can be influenced and potentially modified by the use of simultaneously presented visual (Candas and Dufour, 2005; Huebner *et al.*, 2016; Spence, 2020a; Winzen *et al.*, 2014; though see also Battistel *et al.*, 2024), auditory (Agrawal and Schachner, 2023; Wang and Spence, 2017), and/or even olfactory cues (Sani *et al*., 2022; cf. Böhme, 2019; Fanger *et al*., 1977; Tagliabue *et al*., Ciribini, 2020). As such, it is interesting to consider what role, if any, multisensory cues may play in determining how people perceive and experience ambient humidity.

Although research on the perception of humidity has largely centred on thermal and tactile pathways, a growing body of evidence suggests that additional sensory channels may also be involved, though the strength of this evidence varies considerably as a function of the sensory modality. Water vapour shapes visual experience by influencing ocular moisture (Ito and Takada, 2023), and affects touch through its modulatory effect on skin hydration; these pathways are relatively well documented. Olfactory involvement is plausible, given that humidity acts as a carrier of volatile compounds, though the direction of the effect is complex: while some studies report improved olfactory sensitivity under humid conditions (Kuehn *et al*., 2008), others find no significant effect (Drews *et al*., 2021; Collado and Varela, 2008), and high humidity may, in some cases, suppress olfactory sensitivity altogether. Evidence for auditory and gustatory contributions is more preliminary, resting largely on indirect findings about acoustic propagation and food moisture, respectively (Priyadarshani and Mani, 2024; see also Barbosa Escobar *et al*., 2023); whether specific soundscapes can themselves evoke the subjective feeling of moisture remains an open question. It would therefore be premature to conclude that all sensory modalities contribute meaningfully or independently to humidity perception; rather, the thermotactile pathway appears primary, with other modalities playing modulatory or contextual roles whose precise contributions remain to be established experimentally. Multisensory research shows that olfactory and visual cues modulate taste perception (Spence, 2017), crossmodal interactions shape roughness and texture perception (Di Stefano and Spence, 2022), while sound can influence smell (Spence *et al*., 2026), illustrating a broader sensory interdependence that may similarly characterise humidity perception, though this remains a hypothesis rather than a demonstrated finding in this specific domain.

Although humidity itself is invisible, it sometimes manifests visibly; for example, as condensation in a steam room or as mist and fog in the air. There is also a sense in which ambient outdoor sounds take on a slightly different quality depending on the meteorological conditions. In fact, not only do visual, auditory and potentially also olfactory cues affect the experience of humidity, but both olfactory and flavour perception are sometimes affected by the ambient humidity, depending on temperature and air pressure (Kuehn *et al*., 2008; Philpott *et al*., 2004; Spence, 2017). This is especially apparent in the context of those food artists who, in recent years, have started to popularise their edible/drinkable fog installations (The Times, 2017; Ward, 2022).

Within this multisensory landscape, compensatory mechanisms offer a key window into how the body dynamically reweights sensory inputs. Classical studies show that when thermal cues are diminished, such as when evaporative cooling is limited, individuals shift toward a greater reliance on tactile sensations like stickiness or increased skin friction to infer wetness (Filingeri, 2014b). This demonstrates flexibility not only within the thermotactile system but also invites consideration of how the other senses may similarly compensate when primary cues to humidity become ambiguous.

Perceptions of comfort further underscore the multisensory nature of humidity perception. Comfort is positively related to sensations of warmth and negatively to sensations of dampness (Li, 2005), indicating that humidity is interpreted through a composite evaluation of temperature, moisture, and likely also additional sensory impressions. Taken together, these findings suggest that understanding humidity perception requires expanding beyond a thermotactile paradigm, but they do not yet establish which additional modalities contribute, in what proportion, or under what conditions. Section 3 examines how these perceptual processes play out in the specific context of the built environment, where comfort standards are set and where the practical stakes of humidity perception are most tangible. Yet standard thermal-comfort instruments collapse this composite into a single Predicted Mean Vote or thermal sensation score — a methodological choice that may obscure precisely the multisensory processes this review argues are central. This tension is not merely theoretical. Yang and Moon (2018) demonstrate it empirically in a controlled chamber study: noise level significantly degraded thermal comfort without affecting thermal sensation at all, a dissociation that cannot be captured by any single-scale measure. If acoustic conditions can depress thermal comfort while leaving thermal sensation unchanged, the question becomes urgent: how many other unexamined modalities, olfactory, visual, interoceptive, may be silently shaping comfort ratings in ways that current instruments are simply not designed to detect?

3. Humidity Preferences in the Built Environment

The evidence consistently demonstrates that humidity exerts significant effects on human comfort, though the direction and magnitude of these effects vary substantially by climate zone, season, population characteristics, and individual factors, making context-specific rather than universal standards necessary. At elevated temperatures, higher humidity produces strong negative effects on both comfort and cognitive performance (Tian *et al.*, 2021). For instance, at 30°C, participants reported a 1.5-unit increase in their thermal sensation vote, a rating of how hot or cold they feel, when humidity rose from 40 to 80% RH, and 80% of individuals found the thermal environment unacceptable at the highest humidity level (Jing *et al.*, 2013). Notably, meaningful effects of humidity also appear in winter, showing that it is a year-round concern (Li *et al.*, 2019). For example, an office study in Helsinki found that increasing indoor humidity from 30% to 40% made occupants feel more comfortable, but at the same time led to a perception of reduced air quality which was rated as more odorous and stuffy (Reinikainen *et al.*, 1997).

According to the results of a study in which researchers collected indoor climate data from 37 homes across the United States over the course of the year, most people seem to set their homes to a fairly uniform 17–23°C (Just *et al.*, 2019). These data were then compared to recent global terrestrial climate data looking for the closest match. Remarkably, the average indoor temperature and humidity across the course of the year that matched most closely turned out to be the mild outdoor conditions of west central Kenya or Ethiopia, where human life is first thought to have evolved. What such results suggest is that people tend to set the thermal conditions in their own homes to match the environment that was likely experienced by our ancestors millennia ago (see Spence, 2021). While contemporary home heating has enabled more of those living in the developed world to live in stable thermal conditions, it should be noted that this may have a negative impact on our waistlines (Johnson *et al.*, 2011).

3.1. Individual Differences in the Preference for Humidity?

Given the well-publicised sex differences in preferred ambient temperature (e.g., see Spence, 2021), it is interesting to consider whether there may also be salient individual, or for that matter cultural, differences in the preferred levels of humidity too. Relevant here, it is worth considering what role, if any, adaptation to humidity might play in determining optimal thermal-comfort levels. Adding complexity here are findings suggesting the existence of circadian and circannual variations in the evaluation of thermal comfort in a constant climate (Pöllmann, 1994). The evidence shows wide individual and population-level differences in the tolerance for humidity. A study conducted in Helsinki by Reinikainen *et al.* (1997) demonstrated that women tended to respond more strongly to humidity changes than men, and age influenced sensitivity, with the youngest and oldest groups showing distinct response patterns. Seasonal and geographic factors also played a major role.

Acceptable humidity ranges have been shown to differ sharply between winter (2.9–12.8 g/kg) and summer (3.3–18.8 g/kg), and vary across climate zones; for instance, participants in India are comfortable at much higher absolute humidity levels (17.4–22.6 g/kg) than those suggested by Western standards (Priyadarshani *et al.*, 2023). Such findings indicate that acclimatisation (what might be considered as a form of perceptual adaptation to humidity; see Lam, Cui, Liu, Kong, Ou and Hang, 2021), both seasonal and long-term, substantially shapes the perception and acceptability of humidity, thus meaning that comfort thresholds are not universal but reflect physiological and psychological adaptation to local climatic conditions (Du *et al.*, 2020; Priyadarshani *et al.*, 2023).

Overall, the evidence does not support a single optimal humidity range. Instead, what counts as acceptable humidity is context-dependent, varying with temperature (with lower humidity needed as the ambient temperature increases), season, climate zone, population characteristics, and whether the goal is short-term comfort or long-term population health. It is, however, important to note how virtually all of the published psychological research on people's perception of, and response to, humidity has tended to be based on WEIRDo's. This is the name given to the Western, Educated, Industrialised, Rich, and Democratic societies from which the majority of participants in psychological research are sampled (Henrich, 2024; Henrich *et al.*, 2010a,b; Johnson, 2011; Jones, 2010). What is more, it turns out that more than 90% of all participants in psychology research are North American students studying psychology (Arnett, 2009). Given that this is also likely to be the case in psychological/cognitive neuroscience research on humidity perception and acceptance, then this obviously represents a serious limitation in terms of the generalizability of the existing research. It is striking that this limitation is acknowledged with such frequency and acted upon so rarely. The practical consequence is not merely reduced generalisability but the risk that current comfort standards actively misrepresent the humidity experiences of the majority of the world's population. Given that climate change will disproportionately affect precisely those communities least represented in the existing literature, this is not a peripheral methodological concern but a substantive problem of epistemic justice in the field.

Moreover, research on humidity in the built environment remains heavily centred on healthy, able-bodied adults. Very little is known, for instance, about how humidity is perceived or tolerated by groups whose sensory, physiological, or hormonal conditions differ from the 'standard' participant typically recruited in thermal-comfort research. For example, there are almost no empirical data on how humidity affects people with chronic respiratory or cardiovascular diseases, individuals with disabilities, pregnant or menopausal women, transgender individuals undergoing hormone therapy, or those individuals with sensory-processing differences. These populations may have altered thermoregulatory function, distinct sensory sensitivities, or different vulnerability thresholds, yet their experiences remain effectively invisible in current models. Consequently, existing comfort standards are built on an incomplete evidence base that fails to capture the full diversity of human bodies and lived conditions, revealing an urgent need for more inclusive and representative humidity research in the built environment. These limitations in the empirical literature also have a conceptual dimension: if the very categories used to measure comfort (thermal sensation votes, acceptability thresholds, and so on) have been developed on narrow populations, they may be poorly equipped to capture the multisensory and culturally situated processes that Section 4 argues are central to humidity perception. The evidence reviewed in Section 3 thus points toward a structural gap: the built-environment literature has mapped the comfort consequences of humidity but has not asked why people perceive humidity as they do, nor how sensory, cultural, and individual factors interact to produce those perceptions. It is precisely this gap, the missing architecture of humidity perception, that Section 4 addresses.[4]

4. The Missing Architecture of Humidity Perception

Unlike certain invertebrate and amphibian species, humans lack dedicated receptors for humidity, known as hygrosensors. As a result, the level of ambient moisture must be inferred indirectly through multiple sensory cues: the stickiness or dryness of the skin, musty or absent odours, condensation on surfaces, or changes in the ease of breathing. The evidence base here is uneven: the thermotactile contribution is well established (Filingeri *et al.*, 2014a), olfactory modulation is documented but complex in its directionality (Grabe and Sachse, 2018; Kuehn *et al.*, 2008), and the roles of acoustics (Tronchin, 2021), vision (Priyadarshani and Mani, 2024), and taste (Spence, 2017) rest on more limited and indirect evidence. Yet regardless of the varying evidentiary weight, these findings remain largely siloed, with little consideration of how such signals interact to produce the multisensory experience of humidity, and it is precisely this integration that the present review seeks to address.

Notions of predictive coding (Friston and Kiebel, 2009; Talsma, 2015) and Bayesian multisensory inference (Bertelson and De Gelder, 2004; Ernst, 2012) would seem relevant here, though have not been considered in relation to the

[4] It is worth noting that clothing material constitutes an understudied mediating variable in built-environment humidity perception. Fabric properties such as moisture-wicking capacity, thermal conductivity, and air permeability modulate the thermotactile signals, particularly skin cooling and friction, through which humidity is inferred. This means that the clothed and unclothed body represent genuinely different perceptual conditions, not merely different comfort levels. The intuition is perhaps clearest in contexts such as sauna use, where the absence of clothing maximises direct skin exposure to humid air and may partly account for the qualitatively distinct perceptual experience reported in such settings. The textile comfort literature has engaged some of these questions, but integration with the perceptual framework developed here remains an open avenue.

multisensory experience of humidity thus far. It may also be fruitful to consider the notion of sensory dominance (Hutmacher, 2019) when thinking about humidity perception. It would seem unlikely that the visual dominance that has been documented in so many other examples of multisensory perception would be observed in the case of conflicting sensory cues to the perception of humidity. It is worth being blunt about what this unevenness in the evidence base means.

Describing humidity perception as ‘multisensory’ without differentiating between what is established and what is speculative creates a false impression of theoretical consensus where none yet exists. The olfactory, auditory, and gustatory contributions reviewed here cannot bear the same evidentiary weight as the thermotactile pathway, and treating them as equivalent would be analytically misleading. The more productive question is not ‘how many senses contribute?’ but rather ‘under what naturalistic conditions do secondary modalities become decisive, and through what mechanisms?’ Islam (2026) illustrates why this matters: in his phenomenological study of weather and culinary behaviour, participants did not experience humidity as a thermotactile sensation with optional olfactory accompaniment, they experienced it as a unified atmospheric condition that reorganised appetite, mood, and memory simultaneously.

Laboratory paradigms that isolate single channels are not equipped to capture this kind of integration, and this gap should be acknowledged as a structural limitation of the existing literature, not merely a methodological detail. This limitation is partly conceptual. Much of the existing research continues to rely on the Aristotelian “five senses” model, maintained for its historical authority and its neat alignment with distinct end organs. However, contemporary philosophy and cognitive science recognise many more sensory modalities including balance, proprioception, thermoception, interoception, and pain, revealing perception to be inherently multisensory and integrative (Wilson, 2021). Humidity perception exemplifies this challenge: it does not arise from specialised receptor cells but from the convergence of multiple indirect pathways. Current experimental work, however, still tends to treat these effects as discrete and fragmented, rather than as components of an integrated perceptual field.

In the previous section, we saw how physiologists have made important contributions to this field by conceptualising humidity primarily through the lens of ‘skin wetness’ (Filingeri and Havenith, 2014a, 2015). While this framework offers valuable neurophysiological insight, it remains largely centred on the skin surface and does not fully account for other sensory interfaces, including the eyes, lungs, and nasal passages (Maddux *et al.*, 2016; Takada and Matsushita, 2013), that undoubtedly help to shape lived experience. Emerging ethnographic work (Mazzone *et al.*, in progress) indicates that people may also report sensations such as lightheadedness or loss of balance in very humid environments, pointing to possible proprioceptive or vestibular involvement. Although a recent scoping review on multisensory humidity (Priyadarshani and Mani, 2024) begins to broaden the physiological discourse, it leaves unaddressed the experiential, cultural, and phenomenological dimensions through which humidity is sensed, interpreted, and negotiated in everyday life. This gap underscores the critical role of ethnography and anthropology in advancing a genuinely multisensory and situated understanding of humidity and comfort. Interestingly, when we move away from strictly physiological studies of humidity and embrace more cultural accounts, we encounter the 'neglected' senses such as interoception or proprioception, as we will examine in the next section. Future research may also wish to consider notions of humidity in the beyond-human domain (Abram, 2017).

4.1. An Anthropological Perspective on Humidity

Anthropological research shows that sensory perception is culturally organised rather than universal. Western modernity privileges vision and hearing (Howes, 2003), whereas it has been suggested that for the Amazonian Desana smell may be central of their social order (Classen, 1995); the Songhay of Niger rely on smell, taste, and touch to sense spirits (Stoller, 1989) and the Anlo-Ewe of Ghana treat balance as a fundamental sense (Geurts, 2003). Such accounts demonstrate that what counts as a 'sense', and how sensory cues are linked, varies across cultures, shaping how environments are perceived and thus acted upon. It should be noted that the anthropological evidence base here is necessarily thin: the cases cited are individual ethnographic studies rather than systematic cross-cultural comparisons, and the field of sensory anthropology remains relatively small. The claim is not that these examples constitute statistical evidence for cultural variability in perception, but rather that they establish proof of concept, demonstrating that sensory hierarchies and linkages are not fixed across human groups and therefore cannot be assumed constant in built-environment research. Broader empirical validation of this variability, particularly using psychophysical methods across cultures, remains largely absent from the literature.

While anthropologists of the senses have not explicitly drawn this conclusion, a close reading of their texts suggests that moisture and humidity are frequently associated with the sense of smell. In many ethnographic accounts, for example, environments characterised by high or very low humidity appear to intensify and mediate olfactory experiences, implying that moisture plays a subtle yet significant role in shaping how smells are produced and perceived. This observation points to an intriguing, albeit indirect, link between humidity and olfaction that merits further exploration, as it reveals how environmental conditions can influence sensory experience and cultural perceptions of odours. To the best of our knowledge, while no study in the literature places humidity at the centre of sensorial experience or research methodology, several studies do, at least, make brief mention of it.

In 2022, for example, Idoia Galán Silvo (Silva, 2022), in his article on sensory ethnography in Saudi Arabia, uses the sense of smell as both an analytical tool and a bridge reconnecting him to his homeland. While humidity itself is not the central focus nor immediately perceived, it is through the sense of smell that he comes to associate humidity with memories of his homeland. As he writes: "Permeating my body, the humidity that smelled of soil triggered the smell of stormy summer afternoons in Irun (the Basque Country), my place of origin. In particular, the rain was a moment to perceive the smell of a different earth, its aroma a passageway to my childhood (an unassigned smell in the present recreates a past childhood, as two different earths become soaked)". In this passage, humidity is experienced as an active, boundary-crossing presence that not only envelops the body but also triggers deeply embedded, sensorial memories. It acts as a mnemonic medium, activating past experiences and emotions through both smell and bodily sensation. Far from being a neutral or purely environmental condition, humidity becomes an agent of emotional and temporal transport, dissolving the boundaries between present and past, here and there. Yet, to the best of our knowledge, no research has yet conceptualised a cultural understanding of humidity or its agentic role in everyday life.

In her ethnography among the Tuareg in 1999, Susan Rasmussen also briefly mentions humidity, intriguingly noting that it serves as a vehicle for producing certain smells. In one passage, she describes how the extremely dry climate and intense heat minimise the presence of moisture, making mould and other humidity-related odours rare. However, she also observes that there is less spatial separation and more permeability between various gustatory and aromatic elements. This refers to a kind of fluidity or exchange between different sensory experiences. The elements of taste, smell, and perhaps even touch or sight might blend or influence one another more readily in this environment. It suggests that the dry climate allows for certain smells to move and mingle freely, without being 'blocked' by excessive moisture or a more rigid environmental structure. In this sense, the absence of humidity heightens the interconnectivity amongst the senses.

In their ethnography *Smelling the Monsoon*, Garay-Barayazarra and Puri (2011) examine how Kenyah Badeng communities in the Ulu Belaga region of Sarawak, Malaysian Borneo, perceive and interpret seasonal changes in the weather through multisensory engagement with their surroundings. Based on ethnographic fieldwork conducted between May 2008 and August 2009, they show that people use smell, hearing, touch, vision, and bodily feeling to anticipate humidity, rainfall, and atmospheric shifts rather than relying on meteorological instruments. Among the Kenyah Badeng of Borneo, the senses are named in ways that mirror the Western fivefold model, yet their lived experience of sensing reveals more fluid boundaries. Words for perception often blur across modalities, for instance, *ngening*, meaning 'to hear', can also describe the act of smelling something pleasant. This linguistic overlap points to an understanding of the senses as interconnected rather than discrete. With reference to humidity, Garay-Barayazarra and Puri (2011) show that humidity among the Kenyah Badeng is apprehended through both interoceptive and affective means. High atmospheric moisture is recognised not only through sensory cues like smell or touch but also through inner bodily feelings of heaviness, lethargy, and irritability, locally described as *leko* in their words: "high levels of humidity are predicted when people suffer sleepiness and when they feel irritable, depressed and show a lack of vigour. These feelings are often expressed by the concept of *leko*. For example, *leko t'nao* means feeling heavy, or tired, to go to work, or *leko pisu*, which means feeling without desire to talk" (Garay-Barayazarra and Puri, 2011: p. 25). The same passage demonstrates that humidity is also affective, meaning it is felt as an emotional and mood-laden state. The authors explicitly note that *leko* captures both bodily and emotional tiredness, linking weather conditions to feeling states like irritability or melancholy.

In monsoon-affected climates such as Japan, humidity is depicted as a powerful force that influences both the physical environment and the lived experiences of individuals. Ethnographic research by Golovina (2019) among Russian migrants in Japan reveals how humidity transforms the home from a static shelter into a dynamic, living space, with profound implications for health, maintenance, and emotional well-being. In one passage she writes: "In the online community, women consulted each other about ways to mitigate the growth of multicolored mold and to save clothes, wallpaper, and furniture that were already moldy. Alisa, who lived in Saitama prefecture in a multistory apartment block made of reinforced concrete, told me that she had once developed a severe cough. Eventually, she realized that black mold was growing under her bed on the tatami placed under the carpet to retain warmth. This incident led to a cleaning session and disposal of the carpet" (Golovina, 2019: p. 179).

Humidity might be sensed internally (interoception/proprioception). In ethnographic fieldwork in Uruguay, for example, Wainwright (2017) was concerned with the ways in which breathing is disrupted in the context of living with COPD (chronic obstructive pulmonary disease). People described humidity as 'bad for your breathing', and doctors reinforced this link, advising patients to stay indoors on humid days. This reflects a cultural aetiology in which humid air is considered pathogenic, producing heaviness, fatigue, and breathlessness. Interestingly, ethnographic accounts emerging from this work suggest that sensing humidity in the ‘lungs’ constitutes a form of perceiving one’s internal state, that is, an instance of interoception, in her writings: “I began noticing how often *tiempo feo* and humidity went hand in hand in the discourse of most Uruguayans I met. Uruguay has a temperate climate and I found Uruguayans speaking of the horribleness of humidity (with or without rain) throughout the year. In the summer, striking up conversation was as easy as exclaiming *que calor* (wow, it’s hot!) and in the winter, *que frio* (wow, it’s freezing!). Hearing *hay mucha humedad* (there is a lot of humidity), *que humedo* (wow, it’s humid!), or *es la humedad que mata* (it’s the humidity that kills you) traversed all seasons. When humidity was accompanied by extremes of hot or cold, the day was considered particularly *feo* and required even more safeguarding. Humidity was seen to be particularly problematic for breathing” (Wainwright, 2017: p. 336) This culturally embedded perception of humid air as dangerous for breathing sits in striking contrast to clinical evidence suggesting that regular sauna bathing, a form of controlled, high-humidity thermal exposure, may, in fact, reduce the risk of developing COPD (Kunutsor and Laukkanen, 2023), pointing to a tension between lay cultural etiologies of humidity and its physiological effects under controlled conditions.

In contemporary, less ventilated spaces, where modern design often prioritises aesthetics or energy efficiency over natural airflow, increased humidity can lead to persistent moisture problems. This, in turn, fosters the growth of mould and other damp-related issues (see the Introduction), compelling inhabitants to engage in extensive cleaning practices and unforeseen expenditures in the replacement of furniture/textiles and home refurbishment costs. These ethnographic accounts would appear to suggest that humidity is felt and perceived through a combination of exteroceptive and interoceptive sensing, thus perhaps emphasising a departure from the Aristotelian notion of the five senses.

In the working conceptual framework (Fig. 1) we summarise the evidence found in this research and draw humidity perception as simultaneously a multisensory, inferential and culturally situated process. At its core, the framework holds that: (1) humans lack dedicated hygrosensors and therefore infer atmospheric moisture indirectly from converging sensory signals; (2) the primary pathway involves thermal and tactile integration (the ‘touch blend’), but additional modalities, including olfaction, vision, audition, and interoception, contribute to varying and as yet currently poorly quantified degrees; (3) the weighting of these cues is modulated by prior experience, cultural context, and bodily state. It is worth noting that the mechanisms through which humidity is perceived are still unknown (Sensory Pathway in Fig. 1) and this framework serves as guiding tool resulting from the review conducted in this study.

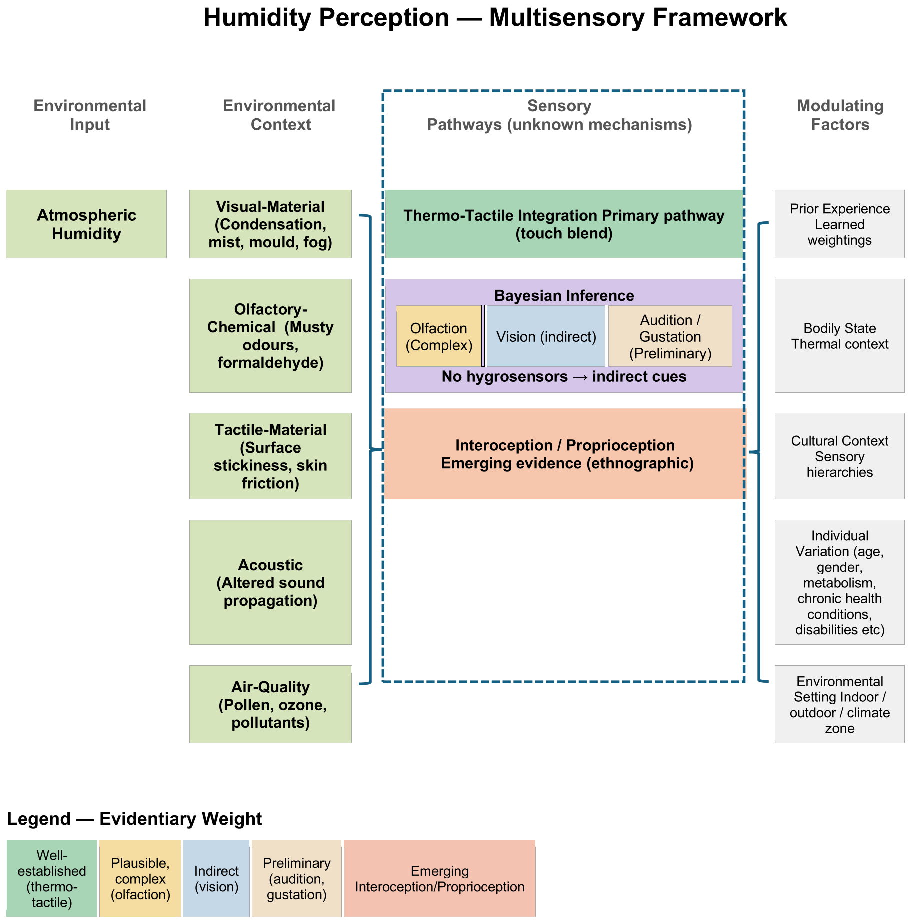

Figure 1. Working framework to understand humidity perception.

5. Conclusions

The evidence reviewed in this paper supports the framework (summarised in Fig. 1): humidity perception is an inferential, multisensory, and culturally situated process in which the thermotactile system provides the primary pathway, modulated by additional sensory channels whose relative contributions vary by context, prior experience, and the cultural organisation of the senses. Crucially, this framework reveals that humidity perception cannot be reduced to a fixed physiological response to atmospheric conditions: the same atmospheric conditions can be experienced as oppressive or pleasurable depending on the degree of personal control (Paciuk, 1990), shaped by culturally specific sensory hierarchies, and mediated by interoceptive and affective states that have been almost entirely absent from the existing experimental literature. Although people usually find humidity uncomfortable when it's too high or too low, they sometimes intentionally choose these extreme conditions, such as in steam rooms or saunas. Those communities living in tropical or desert environments adapt to highs and lows of RH in ways that illustrate how comfort thresholds are not fixed but culturally and physiologically plastic (Tochihara *et al.*, 2022). Control of thermal conditions, including humidity, is becoming increasingly important, especially in the era of climate change. Issues of thermal comfort are becoming an increasingly important aspect of people's comfort in both the indoor and outdoor environment (Hong, Du, Zhai and Matzarakis, 2025; Lam, Pan, Nie, Li, Wu, Yin and Han, 2024; Priyadarshani and Mani, 2024). At the same time, concerns have also been raised that thermal comfort may be contributing to the global obesity crisis (Johnson *et al.*, 2011). What this review also reveals, however, is that the field has a habit of stating this conclusion and then proceeding as if it were settled, when in fact the relative contributions of secondary modalities remain largely unmeasured. The framework in Fig. 1 is therefore best read not as a map of what is known but as a research agenda: it identifies where the evidence is secure (thermotactile integration), where it is plausible but contested (olfaction), where it is preliminary (audition, gustation), and where it has been almost entirely ignored (interoception, cultural variation). Progress will require moving beyond the rhetorical gesture towards multisensory complexity and committing to the experimental and ethnographic work needed to test it.

Clarifying the sensory and perceptual mechanisms by which people detect and make sense of humidity would greatly strengthen studies of thermal comfort, which currently depend on subjective assessments that are difficult to interpret without a deeper understanding of how humidity is actually experienced. For instance, when tactile or thermal cues are weak, individuals may depend more heavily on other modalities such as visual signs of condensation or olfactory cues associated with dampness to infer atmospheric moisture (see Hutmacher, 2019, on the dominance of the visual). Disentangling these multisensory interactions will be essential for those wanting to develop more ecologically valid accounts of humidity perception as experienced under naturalistic conditions and for informing the design of thermally just environments.

Interdisciplinary work between anthropology and perceptual psychology is therefore essential if research on humidity perception is to be advanced. Anthropology reveals that sensory experience is never purely biological: cultures differ in how they define individual senses, in the metaphors and practices through which the atmosphere is interpreted, and in the bodily techniques used to inhabit humid or arid environments (in line with Howes, 2003). Psychology, by contrast, offers tools for examining the mechanisms and multisensory interactions that enable humans to detect humidity. Together, these fields can illuminate how culture shapes the very organisation of the senses, what is attended to, what is ignored, what is felt, and how that feeling is interpreted, leading to a more nuanced account of humidity as both a perceptual and a cultural phenomenon.

5.1. Future Research Directions

Future research should further examine the multisensory nature of humidity perception, with particular attention to audition and olfaction, two senses that remain largely understudied in this context. On the olfactory side, while research on how humidity affects olfactory sensitivity has yielded mixed results, whether specific scents can themselves evoke atmospheric moisture remains unexplored. For instance, eucalyptus may do so through its mental (semantic) associations with steam-filled environments such as Turkish saunas, while musty or damp odours might similarly prime the sensation of a humid atmosphere. On the auditory side, the acoustic qualities characteristic of humid environments, such as the softened, muffled, or otherwise dampened soundscapes produced by moisture-saturated air, have received scant empirical attention. While some work has begun to explore how sound and humidity interact in shaping broader perceptual and comfort judgements (Qin *et al.*, 2024), whether specific soundscapes can themselves evoke or intensify the subjective feeling of moisture remains an open question.

Consider the example of a regular steam room user: eucalyptus oil is often diffused in these high-humidity settings, a practice with deep roots in alternative medicine traditions across Southeast Asia and Europe, where eucalyptus has long been used to support respiratory health (de Boer *et al.*, 2011). Interest in sauna use has grown substantially in recent years as its health and social benefits have become more widely recognised (Geddes, 2026). This is not merely traditional lore: experimental research confirms that 1,8-cineole (eucalyptol), the principal active compound in eucalyptus oil, exerts genuine anti-inflammatory, mucolytic, and antimicrobial effects. Encountering that same scent elsewhere may not only recall its fragrance but also reactivate the embodied memory of damp warmth, condensation, and saturated air. Such cases suggest that certain olfactory cues may ‘carry’ humidity as a sensory trace, triggering the recollection, or even the illusion, of atmospheric moisture in its physical absence. Understanding these associative pathways would likely open up a number of promising avenues for research at the intersection of perception, memory, and environmental experience. Clinical research confirms that the combination of sauna heat and eucalyptus aromatherapy produces measurable physiological effects, including fatigue reduction and autonomic regulation, suggesting the pairing has genuine embodied salience (Wulandari *et al.*, 2023). However, a critical note is essential here. The ambient scent literature provides systematic evidence that pleasant olfactory cues do not reliably encode or amplify multisensory experience: Spence (2020b) documents repeated failures in which fragrancing interventions that were expected to enhance well-being or atmospheric congruence instead produced null or negative results. This pattern should caution against assuming that the associative link between eucalyptus and humid heat will straightforwardly transfer across contexts, and underscores the need for direct experimental testing of olfactory contributions to humidity perception rather than reliance on anecdote or analogy

A further underexplored direction concerns the role of thermal interoception — the perception of internal body temperature, and its potential interaction with perceived humidity under conditions of heat stress. Interoception refers to the sensing of the body's internal physiological state (Nord and Garfinkel, 2022; Toussaint *et al.*, 2024), and there are good theoretical reasons to expect that heat stress, which places acute demands on thermoregulatory systems, may modulate the perceived intensity of ambient humidity. When core body temperature rises, the skin's cooling capacity *via* evaporative sweating is compromised in humid conditions, creating a feedback loop in which interoceptive signals of thermal overload and exteroceptive signals of atmospheric moisture may become difficult to disentangle. This raises the question of whether what people report as 'feeling humid' in hot conditions is partly a misattributed interoceptive signal, an inference about bodily state rather than about environmental conditions *per se*. Experimental paradigms that independently manipulate ambient humidity and core body temperature, while measuring both thermotactile and interoceptive sensitivity, would be needed to test this hypothesis. Given that the populations most vulnerable to heat stress, including those with COPD (Wainwright, 2017) and cardiovascular disease (Klompmaker *et al.*, 2023) are precisely those whose interoceptive systems may be compromised, this line of research has clear clinical as well as theoretical relevance.

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