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Review

Material Dependency of Crossmodal Correspondences in Shitsukan (with a Focus on Food)

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Abstract

In this narrative (historical) review, the emerging literature documenting those crossmodal correspondences that involve material properties such as texture and viscosity, as well as object properties, including shape and size, are both summarized and critically evaluated. Emphasis is placed on those cues to material properties that are available to the nonvisual senses. In this review, we explicitly connect the literature on multisensory *shitsukan* with the growing literature on crossmodal correspondences, specifically those involving material properties. This narrative historical review also draws attention to the possible material dependence of crossmodal correspondences — meaning, for example, that the existence of specific shape–taste crossmodal correspondences may depend on the material from which an object appears to have been made. This suggestion can be framed in terms of the context dependency of crossmodal correspondences, as has also been highlighted elsewhere in the literature.

Keywords

material quality, *shitsukan*, multisensory, crossmodal correspondences, texture

1. Introduction

Recent years have seen a growing interest in the multisensory affective perception of material properties, known as *shitsukan*, in Japan (e.g., Fujisaki, 2020; Komatsu and Goda, 2018; Nishida and Nishino, 2026; Spence, 2020c). At the same time, however, there has long been a tendency amongst many

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material scientists to focus on those material qualities that can be perceived visually (e.g., see Komatsu and Goda, 2018, for a review). In part, this presumably reflects the more general bias toward vision research in human participants (Hutmacher, 2019), but perhaps also the fact that material properties (e.g., such as glossiness and iridescence) can nowadays be digitally rendered more easily visually than can specific material properties in any of the other senses (Komatsu and Goda, 2018; Nishida and Nishino, 2026; Spence, 2020c). Nevertheless, it is important to recognize that material quality perception, or *shitsukan* (referring more to the affective, than the sensory-discriminative, qualities of materials), is most definitely a fundamentally multisensory concept (see Spence, 2020c). What is more, various material properties can often be inferred/perceived only on the basis of the sensory cues that are present in one or more of the nonvisual senses.

At the outset, though, it is worth considering what actually counts as a material property.[1] A material property refers to an intensive property of a material, that is, a physical or chemical property that does not depend on the amount of material that is presented. For instance, viscosity and thermal diffusivity (Bergmann Tiest and Kappers, 2009) are both considered material properties. Although neither an object's size nor its shape are, strictly speaking, material properties (one might instead classify them as object properties), they will nevertheless be considered in this narrative review insofar as these attributes of objects (rather than materials) are involved in many of the crossmodal correspondences that have been reported to date. What is more, shape properties (such as the fracturability statistics, and hence how sharp the fractured surfaces of materials are) may, in certain cases at least, turn out to be correlated with material properties. Or consider here whether, as suggested by Spence (2020a), there is a natural correspondence between the shape of leafy greens and their likely (bitter) taste qualities (see Fig. 1). Once again, this might be considered as a material, and perhaps food-specific, crossmodal correspondence (e.g., Choong *et al.*, 1992).

Shitsukan refers not to a single sensory attribute obtained from a single sensory modality, but rather to the multisensory and affective perception of material properties — such as luxury or authenticity — that emerge from the integration of multiple sensory inputs (e.g., visual gloss, tactile texture, auditory feedback). These unified impressions are not only directly derivable

[1] The taste or flavour of food or drink perceived through the chemical senses are presumably determined by a food's material properties, but should not necessarily be considered as material properties in their own right. Taste, like mouthfeel, is a description of what we feel/experience when consuming something. By contrast, our assessment of the texture of a food, such as its crispiness, constitutes an assessment of its material properties, rather than necessarily what it feels like to us (Bourne, 1982; Spence, 2015; Spence and Piqueras-Fiszman, 2016; Zampini and Spence, 2004).

Figure 1. Does the curvilinearity of leafy green vegetables provide any cue to taste? Figure reprinted from Spence (2020a), with permission.

from a single modality (e.g., only vision or only touch), but also arise as a coherent percept through crossmodal multisensory integration, grounded in both sensory and affective processes. By emphasizing the fact that *shitsukan* is inherently material-dependent, we argue that attention to material dependency is essential for establishing a coherent theoretical framework for crossmodal correspondence research, particularly in the context of foods.

The last few years have seen an explosive growth of research interest in the topic of crossmodal correspondences (see Motoki *et al*., 2023; Spence, 2011, 2018, for reviews). However, it is worth noting that the majority of the research that has been published in this area to date has tended to focus on crossmodal correspondences between auditory and visual stimuli (e.g., Evans and Treisman, 2010; Gallace and Spence, 2006; Marks, 2004; Parise and Spence, 2009, 2012; Spence and Sathian, 2020; Walker, 2016a,b). Although to a lesser extent, studies have only recently started to emerge documenting the existence of crossmodal correspondences between tangible textures and other modalities, such as basic tastes (Pistolas and Wagemans, 2023; Slocombe *et al*., 2016), perhaps because of the greater methodological challenges that are associated with the presentation of stimuli outside the audiovisual domain. As such, it can be argued that there is something of a gap in the published empirical literature as far as our understanding of the existence of, not to mention the most appropriate explanation for, those crossmodal correspondences that involve the tactile/material properties that have been published in recent years.

In this review, we therefore critically evaluate the emerging literature on crossmodal correspondences involving material properties, including visual appearance (e.g., of gloss or irridescence), texture (e.g., rough or smooth, surface softness, granularity), perceived through vision (Cavdan *et al.*, 2021; Nalbantoğlu *et al.*, 2024), touch/haptics (Barnett-Cowan, 2010; Suzuki *et al.*, 2024), and also by means of auditory cues (e.g., Bulusu and Lazar, 2024; Di Stefano and Spence, 2022) and scent (e.g., Nevo *et al.*, 2016). Compressability, hardness, weight, and thermal conductance are all material properties that are perceived primarily through the sense of touch (Spence *et al.*, 2019; Walker, 2012). Note that audition can also provide information concerning viscosity, and thus, indirectly, about a liquid's temperature (e.g., as in the case of the sound of pouring liquids; Agrawal *et al.*, 2020; Agrawal and Schachner, 2022; Velasco *et al.*, 2013a, b).[2] Auditory and visual crossmodal correspondences have also been reported with haptically perceived liquid viscosity (Asad, Spiller and Jonas, 2016). Furthermore, certain scents, such as the aromas of ripe fruits, may convey potentially useful information about their ripeness/softness (and hence sweetness, or energy content) too (Nevo *et al.*, 2016). Tactile/material properties can form crossmodal correspondences with other sensory modalities, including vision, audition and olfaction. Sensory input from these nontactile modalities can provide information about tactile/material properties or modulate the actual perception of material properties experienced through the sense of touch.

The shape and size of small objects can be perceived directly through vision and touch/haptics, and relevant cues may allow a listener to infer the likely size and shape of a sounding object (Spence and Di Stefano, 2024; see Spence and Zampini, 2006, for a review). Cues provided by the chemical senses may, on occasion, potentially be relevant to the assessment of size too (see Ngo, Velasco, Salgado, Boehm, O'Neill and Spence, 2013). Although both size and shape are object, rather than material, properties, they are nevertheless included in this review given the number of crossmodal correspondences that have recently been documented between geometric shapes and temperature, texture, and taste attributes (e.g., Juravle *et al.*, 2022, 2024; Juravle and Spence, 2024). Note also that object shape can sometimes modulate people's affective responses to material properties, such as felt texture (e.g., Etzi

[2] Auditory cues are typically generated by the contact with a material or its transformation. Similarly, according to Barwich (2020), olfactory cues often provide information about those materials/stimuli that are in a state of transformation.

et al., 2014), while an object's size is known to influence people's judgements of its apparent weight, as in the well-known size–weight illusion (Ross, 1966). It is intuitively recognized that the shape and size of an object can influence affective perceptions of material properties of the object itself — such as impressions of comfort or luxury. However, the affective perceptions may be underpinned by crossmodal correspondences between different sensory modalities. In this review, therefore, we discuss the applicability of the theoretical framework of crossmodal correspondences to explain the affective perception of material properties (i.e., *shitsukan*).

Kanaya *et al.* (2016) investigated the existence of various crossmodal correspondences between vision, audition, and touch in terms of the perceptual properties of wood. Yeomans *et al.* (2008) tested the hypothesis that the perceptual material property estimated in a given modality was to some extent statistically correlated with properties estimated by other senses in the case of natural objects (namely woods). The results revealed that there were significant positive correlations between vision and touch, and between audition and touch, thus supporting the hypothesis of the statistical learning of perceptual properties as a function of sensory modality.

Cosmetics offers another intriguing, not to mention rapidly growing, area for multisensory research concerning crossmodal correspondences that are linked to the *shitsukan* of skin creams and lotions (see Spence and Zhang, 2024, for a review). Skincare cosmetic products are typically formulated to evoke pleasant sensations (and thus emotions) in multiple senses. Pleasant feelings can, in turn, facilitate the repeated long-term use of the product by customers. As a result, the customer may repeatedly experience the crossmodal association between the tactile texture and odour of the skincare product. As such, the repetitive experiences we sometimes encounter in everyday life can help to establish (and explain) those crossmodal correspondences that are explained by both statistical correlations and possibly also the emotional-mediation account. In fact, Courrèges *et al.* (2021) reported that when a person particularly likes the odour of a cosmetic product, their liking for its texture also tends to increase.

Another study investigated the effects of colour, odour, and texture on the quality and liking of body lotion. Wagner *et al.* (2020) reported an empirical study of body lotion showing that a tactile material property (texture) may have a significantly stronger effect on the experience of the user of that product than colour and odour.[3] Once upon a time, when organic clothing dyes had strong odours, there would likely have been a crossmodal correspondence

[3] Though, of course, it is difficult to directly compare stimuli across the senses.

between colour and odour (Spence, 2020a).[4] However, the development of synthetic chemistry at the end of the 19th century led to the emergence of many odourless dyes (see Blaszczyk and Spiekermann, 2017). There have, in other words, been statistical relationships between the multisensory material properties of natural objects and materials, some of which may have changed (or else simply disappeared) over the course of history.

1.1. Crossmodal Correspondences Involving the Material Properties of Foods

As the eminent biologist J. Z. Young noted more than half a century ago, food is essential to our survival (Young, 1968). As such, it makes sense that crossmodal correspondences involving the material properties of foods should be especially important/relevant to us. One of the important material properties of foods is softness, and it must have an association with ripeness (Speirs *et al.*, 2002). Ripeness is both a state and an attribute of foods that determines their suitability for consumption. Ripeness can be perceived by smell, touch, vision and taste.[5] Thus, there is presumably a crossmodal correspondence between the volatiles signalling ripeness and softness in nature (Melin *et al.*, 2019; Nevo *et al.*, 2016, 2022). Another example is that visually warmer hues tend to be associated with the ripeness of fruits (e.g., think only of a red apple or a yellow banana, Foroni *et al.*, 2016; Rizzo *et al.*, 2023). Raevskiy *et al.* (2022) also reported an association between warmer hues and sweetness. Crossmodal correspondences between the material properties of food related to ripeness are then presumably established from the accumulated experience of which perceptual states of food happen to be associated with ripeness. In other words, the sensory system acquires and internalizes ecological statistics that allow crossmodal cues to serve as reliable indicators of ripeness, rather than deriving inferences about ripeness through explicit reasoning alone.

1.2. Shitsukan Involving the Material Properties of Foods

Food *shitsukan* emerges from the integration of multiple material properties that are registered across distinct sensory modalities, including oral haptic texture, visual surface qualities, and auditory feedback during consumption. First, consider here, for example, only how while the tactile attributes of food texture are not part of the standard definition of flavour (see ISO, 1992, 2008), a food's texture nevertheless constitutes one of the most important sensory cues driving people's food avoidance behaviours (e.g., Galler and Varela, 2024;

[4] This is thought to have been what enabled a blind individual to work effectively in sorting the clothes at a laundry several centuries ago in Germany (see Spence, 2002).

[5] And perhaps also auditorily, as when certain fruits are tapped, or rapped with the knuckles to determine their ripeness (as in the case of watermelons).

Prescott, 2012). Furthermore, young children do not like complex food textures, and this may be attributable to the uncertainty concerning what exactly they are eating, especially if the texture indicates the presence of multiple distinct material properties (see Chow *et al.*, 2024). Second, the visually perceived material properties of foods, such as, for example, their glossiness have often been reported to be highly desirable in the context of certain foods (Arce-Lopera, Masuda *et al.*, 2012, 2013; Murakoshi *et al.*, 2013). Third, auditory cues (e.g., crunchiness or crispiness) also convey diagnostic information about the material state of foods, and have been linked to perceptions of freshness in produce or to the fat content in fried and baked goods (see Spence, 2017; Weiss, 2001). One possible explanation for the latter observation is that foods that are noisier on consumption may be correlated with the preservation of nutrients in the case of fresh produce while signalling the fat content of fried and baked goods (though see Kita *et al.*, 2007; Salvador *et al.*, 2009; Van Vliet *et al.*, 2007; Varela *et al.*, 2008, for evidence that appears, at least at first glance, to run contrary to such a suggestion). Taken together, food *shitsukan* is fundamentally multisensory and rooted in the perception of material properties that serve to scaffold crossmodal associations and influence hedonic responses during consumption.

1.3. The Relationship Between Crossmodal Correspondences and Shitsukan Involving the Material Properties of Foods

The relationship between crossmodal correspondences and *shitsukan* becomes particularly salient when considering foods whose material properties convey affective and functional meanings. In *shitsukan* research, sensory cues such as visual glossiness (Arce-Lopera *et al.*, 2012, 2013; Murakoshi *et al.*, 2013), viscosity from visual (Kawabe *et al.*, 2015) or haptic input (Cavdan and Drewing, 2025) have been shown to elicit not only perceptual estimates of material states but also affective impressions. The affective qualities arise from stable statistical correlations between a food's material state and its sensory feedback and are acquired through embodied experience rather than semantic reasoning. Crossmodal correspondences involving food materials — for example, associating high-pitched sounds with brittleness, or bright colours with freshness — can be interpreted as emerging from the same perceptual–affective mechanisms that also underlie *shitsukan*. This view helps clarify that crossmodal correspondences are not merely category-driven or strategically inferred; instead, they reflect implicit, material-based knowledge (material knowledge in short) that shapes how people anticipate the taste, texture, or edibility of foods before consumption. In this way, *shitsukan* research provides a theoretical foundation when it comes to explaining how and why certain crossmodal correspondences exhibit systematic material dependence in food perception.

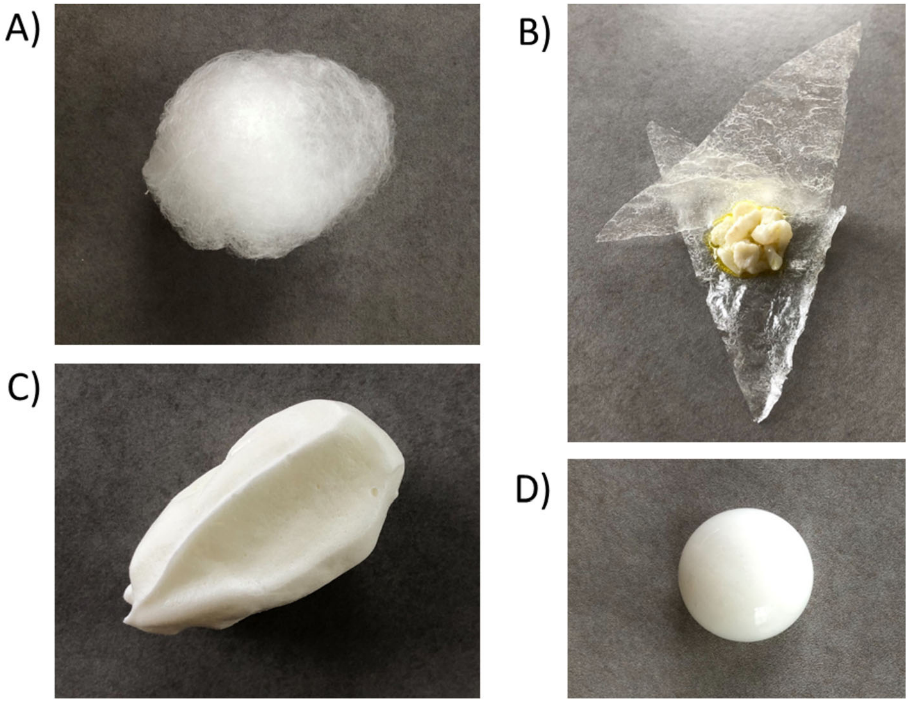

Figure 2. The shape of taste: four amuses-bouche served to diners at Kitchen Theory in London. Diners were invited to guess which of the colourless bites was associated with each basic taste (sweet, sour, bitter, and salty). Notice how in this real-world example, the basic taste quality might be inferred from abstract correspondences between shape and texture, but there might also be semantic knowledge, such that candyfloss (cotton candy) is traditionally a sweet food. Figure reprinted from Spence *et al*. (2019), with permission.

Spence *et al*. (2019) conducted a study that was designed to assess whether crossmodal correspondences could be demonstrated between various visually perceived material and shape properties and the four most commonly studied basic tastes (namely bitter, sweet, salty, and sour). The London-based chef Jozef Youssef created a set of four off-white amuses-bouche for use in the project (see Fig. 2). These stimuli were presented to diners in the restaurant setting, and visually to participants online who were tasked with trying to discriminate which of the four amuses-bouche was intended to be matched with each of the basic tastes. The results of an online study conducted in two countries (mainland Spain and the UK) demonstrated that the majority of those tested did indeed associate these four edible bites with the appropriate basic taste (i.e., as had been intended by the chef). It is interesting to note here how, in this case, people's decisions might have been based both on their knowledge of food materials and their typical taste properties (such as cotton candy which is only ever made from spun sugar) and more abstract angularity–taste, and symmetry–taste crossmodal correspondences (see Salgado-Montejo *et al.*, 2015; Turoman *et al.*, 2018). At the same time, however, it is also worth recognizing how those who took part in this particular gustatory challenge were engaged in a discrimination task (i.e., deciding which of four basic tastes to choose), rather than trying to identify which of many different possible correspondences might have been most strongly associated with the visually presented stimuli in this case. Future studies could adopt reaction-time-based psychophysical paradigms (e.g., Implicit Association Test, or crossmodal congruency task) to test whether the visual–gustatory correspondences observed in previous empirical study exert implicit effects on perception and decision speed.

2. A General Foundation on Crossmodal Correspondences

2.1. Multiple Explanations for Crossmodal Correspondences

The most powerful explanation for crossmodal correspondences that has been put forward to date is in terms of the internalization of the statistical regularities of the environment (Spence, 2011).[6] At the same time, however, certain other correspondences, such as those between specific visual stimuli and music, and between fragrance and colour, would appear to be explained in terms of emotional mediation (what are sometimes referred to as hedonic correspondences) instead (see Schifferstein and Tanudjaja, 2004; Spence, 2020b; Spence and Di Stefano, 2025; Velasco *et al.*, 2015). It has been suggested that a small number of structural (or neurophysiological) correspondences may be involved in matching intensity across the senses due to putatively common neural coding (Stevens, 1957), though it is worth noting that this intriguing early suggestion has yet to be validated empirically. Finally, semantic, or perhaps better said lexical (see Walker, 2012), correspondences have also been postulated.[7] It is, though, as yet still currently unclear how certain of the crossmodal correspondences that have been documented empirically in the literature to date (including those that involve material properties) should be explained. It is also worth considering whether, under certain conditions, there may be an inferential component to crossmodal correspondences, e.g., as when they are used in the context of marketing, or other forms of, communications

[6] In fact, Ernst (2007) demonstrated how rapidly such crossmodal correspondences between unrelated sensory dimensions can be learned such as, in his study, haptic compressability and surface reflectance.

[7] Importantly, however, there is no robust evidence for the existence of crossmodal correspondences based on perceptual similarity (Di Stefano and Spence, 2024; though see also Spence, 2022), nor is there any convincing evidence for the existence of amodal sensory dimensions (Spence and Di Stefano, 2024b).

(see Schloss *et al.*, 2018; Spence and Van Doorn, 2022). That is, it would seem possible that when the participants in laboratory (or online) studies investigating crossmodal correspondences are forced to choose, they may try and figure out what intention is being communicated by the experimenter without necessarily experiencing the correspondence themselves. Such a tendency may be all the more pronounced in the case of marketing communications that are explicitly based on some form of crossmodal correspondence.

Relevant to the statistical account, Ernst (2007) conducted an intriguing study showing that participants were able to acquire a crossmodal correspondence between two otherwise unrelated material properties, namely the luminance of a visually presented surface and its felt stiffness. Stiffness is a haptically determined stimulus property that is not correlated with the luminance properties of materials in the natural environment. Nevertheless, a short period of training proved sufficient to establish such a crossmodal correspondence. In particular, the participants in Ernst's intriguing study were exposed to multisensory stimuli in a virtual-reality scenario where an artificial correlation had been introduced between the stimulus dimensions. In particular, for one group of participants, the stiffer the object, the brighter it appeared, while this mapping was reversed for another group of participants. A significant change in participants' discrimination performance was highlighted when their responses to congruent and incongruent pairs of haptic stimuli were compared before and after training. These changes, or crossmodal correspondences, were likely internalized as a change in the distribution of the relevant coupling prior (see Chen and Spence, 2017, for a review). Given that all of the training in this particular study took place in an experimental session lasting for no more than an hour or so, it is easy to imagine how much stronger coupling priors might be for pairs of stimuli that have consistently been correlated over the course of an individual's lifetime (such as the pitch–size correspondence; Gallace and Spence, 2006).

Taken together, there are a number of plausible, and by no means mutually exclusive explanations for the existence of the wide range of crossmodal correspondences that have been documented to date. Although, as noted already, the majority of studies of crossmodal correspondences have tended to focus on associations between auditory and visual stimulus attributes (or perceptual features), it would seem likely that the same conclusions and putative range of explanations likely applies to those crossmodal correspondences involving material qualities as well.

2.2. The Transitivity of Crossmodal Correspondences

While crossmodal correspondences are typically studied between pairs of sensory modalities, there is growing interest in whether these associations might be connected in a transitive fashion across three or more senses. That is, if two separate pairs of crossmodal correspondences happen to share the same sensory attribute, crossmodal correspondences can occur across three modalities. This suggests the putatively transitive nature of crossmodal correspondences, where associations between two modalities may emerge directly through a shared link with a third sensory modality. For example, consider here only how heavier objects are associated with a darker visual appearance (e.g., many absorbent materials become darker when wet), and tend to make a lower-pitched sound when struck or dropped (Walker *et al.*, 2017). Based on such crossmodal associations, one might also expect the crossmodal correspondence between darker visual appearances and lower-pitched sounds. In fact, several studies have reported a direct association between darker visual appearances and lower-pitched sounds (Marks, 1974, 1987).

The transitive nature of crossmodal correspondences between the visual, auditory and taste modalities has also been noted: Consider here only the fact that dark colours such as black and brown tend to be associated with bitterness (Spence and Levitan, 2021; Velasco *et al.*, 2023, for a review), while bitter tastes tend to be associated with lower-pitched sounds (Crisinel and Spence, 2009, 2010). Once again, dark colours and lower-pitched sounds are directly associated (Marks, 1974, 1987; Walker *et al.*, 2017). However, since the dominant sensory cue (e.g., colour, sound) evoking taste associations may differ depending on the material properties of the food under consideration, the transitivity of crossmodal correspondences may not always occur (for example, a dark and soft chocolate may taste more bitter than a dark and hard one). An interesting topic for future research would therefore be to investigate whether the transitive nature of crossmodal correspondences depends on the material properties of foods.

2.3. Cross-Cultural Differences in Crossmodal Correspondences

The material and sensory associations that underpin crossmodal correspondences may also vary across cultures. While some statistical correlations in the environment are plausibly universal (e.g., larger objects characteristically generating lower-pitched sounds upon impact) whereas others are shaped by culture-specific patterns of experience, including the culturally learned statistical associations between food colours, say, and particular tastes. For instance, some cross-cultural differences in crossmodal correspondences between tastes and visual features have been observed (e.g., Bremner *et al.*, 2013; Raevskiy *et al.*, 2022; Wan *et al.*, 2014; cf. Jacquot *et al.*, 2016, on some subtle cross-cultural differences in the context of colour–odour crossmodal correspondences). And while an extensive body of empirical research now demonstrates that people tend to associate sweetness with roundness, and angularity with the other basic tastes (see Spence, 2023, for a review), that was not true when the Himba tribe of rural Namibia were tested (Bremner *et al.*, 2013; Caparos *et al.*, 2013). Although the latter study was small, and the methods of analysis somewhat unconventional, there is, as yet, still no obvious explanation for this unexpected result. However, when seen through the lens of crossmodal correspondences involving material properties being mediated through material knowledge/familiarity, one might speculate as to whether the Himba were simply unfamiliar with the material properties of different kinds of chocolate.[8] Thinking here in terms of material context dependency, one might therefore want to consider what the fracture properties of typical bitter-tasting foods that are familiar to the Himba in their local food culture are like. In the context of cross-cultural research, it might also make sense to consider the use of the appropriate local foods in future cross-cultural crossmodal correspondences research with this group, rather than assessing correspondences with a material foodstuff that they happen to be unfamiliar with.

2.4. *Crossmodal Correspondence* versus *Crossmodal Effects*

Before looking at the relationship between the material properties of foods and the crossmodal correspondences they entail in the next section, it is important to distinguish the existence of a crossmodal correspondence from whether or not a crossmodal effect can be demonstrated empirically. The latter refers to the fact that the stimuli presented in one sensory modality can sometimes affect the perception of those stimuli presented in another modality. So, for example, when one sees a red candy, this will likely lead the majority of people to expect that it would taste sweet (of course, if the food material happens to be a salsa rather than a candy then the expectation may be of spiciness instead; fort example, see Shermer and Levitan, 2014). The expectation (which one might conceptualize in terms of predictive coding) may also affect the real taste of the candy, or salsa, when tasted or consumed.

On the other hand, given that crossmodal correspondences have been defined as the sometimes surprising crossmodal associations that have been demonstrated between two stimuli that are seemingly unrelated, if the taste corresponds closely to the colour of a beverage, then there may be no crossmodal effect, whereas if the expectation set by the colour is somewhat (though not too) different from the actual taste of the drink, say, then a crossmodal effect may be observed. Here, in case the expectation (no matter whether conscious or implicit) based on the colour is completely violated, colour cues may be ignored altogether (or else lead to a disconfirmation of expectation response; see Yeomans *et al.*, 2008). Understanding the difference between

[8] According to the emotional-mediation account of crossmodal correspondences, if the association between taste and shape were to be based on the emotional response to basic tastes, then there are well-established individual differences in the liking of dark chocolate that might also become relevant here (cf. Crisinel and Spence, 2012).

crossmodal correspondences and crossmodal effects is important when it comes to determining whether the visual, auditory, and tactile properties of materials are perceived as associative connections or whether a sense modality influences the perceptual rating of sweetness, weight, and warmth, for example. One other point to consider here is whether the observer needs to believe that the sensory cue is meaningfully related to the judged stimulus, in order for one to influence the other.

Crossmodal effects can be quantitatively measured using a range of behavioural and psychophysical measures, such as reaction time, accuracy, and rating scales. Indeed, previous studies have used a variety of psychophysical methods, each of which probes a different aspect of information processing. Reaction time tasks are frequently used to reveal facilitation effects, with crossmodally congruent stimuli being processed more rapidly than incongruent ones. Discrimination task or accuracy-based paradigms assess whether the presence of a congruent stimulus in one sensory modality enhances perceptual performance in another. Rating scales and magnitude estimation tasks reveal the impact of crossmodal effects on subjective judgements. For example, the perceived intensity or hedonic value of a stimulus can be altered when it is paired with a stimulus from another sensory modality. In forced-choice paradigms, participants are asked to explicitly select or match crossmodal stimulus pairs, thereby revealing how well the paired sensory modalities are perceived to be aligned. Finally, priming and adaptation paradigms allow one to examine how prior exposure to a stimulus in one sensory modality alters subsequent perceptual or cognitive responses in another sensory modality. Collectively, the aforementioned experimental methods provide converging behavioural evidence for crossmodal correspondences, while varying in their sensitivity to implicit *versus* explicit forms of multisensory integration.

2.5. Heterogeneous Methodologies in Crossmodal Correspondences Research

The methodological approaches that have been used to identify crossmodal correspondences across the literature are heterogeneous. Some studies investigated crossmodal correspondences by means of behavioural facilitation effects (e.g., faster reaction time under crossmodally congruent conditions) reflecting a methodological tradition rooted in controlled psychophysical experimentation (e.g., Evans and Treisman, 2010; Parise and Spence, 2012). The aforementioned studies typically treat crossmodal correspondences as measurable enhancements in speeded task performance under crossmodally congruent conditions.

Other studies, by contrast, rely more heavily on descriptive, associative, or self-report-based methods, including free-association tasks, matching paradigms, or questionnaire data. Such approaches often lack systematic experimental manipulation. As a result, the type of crossmodal correspondence reported can range widely. This diversity in methodological practice raises significant challenges for theoretical interpretation, as different definitions of crossmodal correspondence may not be comparable across studies.

This variability is particularly pronounced in the food domain, where researchers frequently exploit the relative ease of presenting visual food stimuli and collecting self-reported taste associations in a forced-choice paradigm. Because food perception is inherently multisensory and culturally scaffolded, many studies draw on intuitive judgements that may reflect culturally learned statistical correlations rather than crossmodal correspondences grounded in stimulus structure. While the growing body of empirical studies have emerged, the aforementioned research has also increased methodological heterogeneity in stimulus selection, experimental design, and interpretive criteria. Consequently, comparing findings across studies or extracting generalizable principles about the mechanisms underlying crossmodal correspondences in food perception remains a challenge.

3. Crossmodal Correspondences Involving the Material Properties of Foods

Crossmodal correspondences between sensory attributes, such as shape, colour, sound, and various material properties are diverse and often dependent upon the context in which they happen to be encountered. The following examples illustrate a broad variety of such correspondences in the context of food, highlighting some of the complex ways in which multiple sensory cues may conjointly influence the perception and people's expectations regarding the material properties of foods (for an overview, see Table 1).

3.1. Material Knowledge and Ambimodal Crossmodal Correspondences

Are crossmodal correspondences involving material properties moderated/mediated by material (knowledge)? Such a suggestion might, for example, seem plausible if one considers how a glossy appearance is often associated with fat in the case of foods (see Spence, 2021, for a review), but possibly also with hardness and smoothness in the case of those nonfood objects that are lacquered?

Empirically, dark chocolate may be more likely than milk chocolate to break into angular pieces given the higher concentration of cocoa increases the chocolate's fracturability — described as a characteristic 'snap'. This observation may lay behind the association that has been reported in the literature between the macroscopic properties and fracturability in chocolate samples (Afoakwa *et al.*, 2008, Zhao *et al.*, 2018). While Afoakwa *et al.* showed that particle size distribution and composition influence macroscopic rheological

Table 1.
Material properties associated with particular crossmodal correspondences

Nature of the material property	Modality	Target objects	Observable crossmodal correspondence	Example	Reference
Glossy	Vision	Food	Glossy-taste	A food having a glossy appearance looks like it contains fat	Spence (2021)
Glossy	Vision	Inedible lacquered object	Glossy–hardness; Glossy–smoothness	A lacquered object with glossy texture appears both hard and smooth	Tanizaki (2001)
Bright	Vision	Chilli pepper	Hue/brightness taste	People expect that a brighter red chilli will taste hotter than a darker one, resulting in a brightness–taste correspondence	Shermer and Levitan (2014)
Sharp-edged pieces when the material fractures	Vision	Chocolate	Shape–taste; Shape–hardness	A chocolate with a sharp edge looks bitter and hard to break	Gallace *et al.* (2011)
High-pitched sound when the chocolate breaks	Audition	Chocolate	Sound–taste; Sound–hardness	A chocolate producing a high-pitched note sounds hard and thus bitter	Not confirmed yet

and textural properties of dark chocolate Zhao *et al.* discuss the influence of cocoa and the amount of fat content on hardness and fracturability of dark chocolate samples, but it remains unclear whether dark chocolate tends to break into sharper pieces. Intriguingly, shaping chocolate into round or angular forms has been shown to give rise to a shape–taste expectations — regarding bitterness or sweetness — which, in turn, sometimes influence taste perception (e.g., Gallace *et al.*, 2011; Ngo *et al.*, 2011; Ngo and Spence, 2011; Wang *et al.*, 2017). Similarly, hard objects tend to resonate at high frequencies, and when broken, they tend to form sharper fragments than do soft objects (see Parise and Spence, 2012, for a general overview). Researchers have also attempted to distinguish the cocoa content of chocolate based on the sound it makes when broken (Badak-Kerti *et al.*, 2020). One might therefore infer

Figure 3. In the case of wine gums (a popular traditional confectionary item in the UK), it could be argued that the association between shape and taste/flavour (i.e., named type of alcoholic drink — hock, rioja, port, claret, chablis, gin…) is arbitrary in Walker-Andrews' (1994) terminology. This contrasts with the angularity of chocolate which exhibits more angular fracture properties the higher the cacao content.

a chocolate sample to be bitter based on nothing more than the high-pitched sound it makes when it breaks. Although Badak-Kerti *et al.* (2020) demonstrated that cocoa content can be discriminated based on the texture index derived from the acoustic signal of chocolate fracture, their study does not provide evidence regarding human perceptual judgements (e.g., perceived pitch) of fracture sound. There is, however, unlikely to be any such physical relationship in the case of various other food materials, such as, for example, gummy candies (see Fig. 3). This can be interpreted as an example of material dependency in crossmodal correspondence in foods.

3.2. Crossmodal Correspondences between Sound, Taste, and the Qualities of Foods

It has been suggested that when consuming fresh foods, the noisiness of consumption might signal the preservation of nutrient content (Spence, 2017). When a fried chip is dry, a high-pitched sound is produced. On the basis of such a learned association, one might expect crispiness when a chip is chewed (e.g., Dacremont, 1995; Spence and Zampini, 2006), and this might give rise to the expectation of a particular taste experience, or perhaps hint at the energy density of the food (cf. Spence and Piqueras-Fiszman, 2016). Recently, Pistolas and Wagemans (2023) reported that crispiness is associated with saltiness.

The observed crispiness–saltiness crossmodal correspondence can be driven by statistical correlation, given that salted chips are highly prevalent. Alternatively, the sound–crispiness and crispiness–saltiness associations may be linked, causing people who eat foods that make high-pitched noises when consumed to experience increased saltiness along with crispiness.

A variety of experimental paradigms have been used to investigate crossmodal correspondences between texture and taste in food perception. For instance, in Pistolas and Wagemans' (2023) first study, the participants took part in an online matching task. They were asked to pair texture descriptors (e.g. soft, crispy, crunchy, sandy) with basic taste adjectives (e.g. sweet, salty, sour, bitter) using a forced-choice paradigm. In the second experiment by Pistolas and Wagemans (2023), participants were asked to provide examples of typical foods for each basic taste. For example, chocolate was associated with sweet, crisps with salty, lemons with sour and chicory with bitter. The researchers then assigned each answer to one of the predefined texture categories (such as soft, crunchy, crispy, or sandy). This classification was carried out collaboratively by multiple trained coders, and final decisions were made based on majority agreement. In the third experiment, participants took part in a controlled tasting procedure in which participants evaluated sixteen standardised food samples: marshmallow cubes (soft); rice cereal treats coated with white chocolate (crispy); almond–white chocolate clusters (crunchy); and almond flour–based sand cookies (sandy). These foods were infused with different taste agents (e.g. sugar, salt, citric acid and caffeine). Participants rated the perceived texture and taste intensity, hedonic response and associated sensory impression using an 11-point Likert scale.

The choice of paradigm depends on the researcher's objectives and practical considerations, such as the feasibility of recruiting an adequate number of participants for each method. The Implicit Association Test (IAT) is commonly used in crossmodal correspondence research to detect involuntary associations. However, IAT-based feeding experiments are uncommon in the field of food texture and taste crossmodal correspondence. That is, studies primarily involve explicit matching tasks and the recording of sensory and hedonic evaluations, particularly in experiments involving the consumption of food samples on site.

3.3. Crossmodal Links between Colour and Touch

Previous studies have reported crossmodal associations between tactile sensations and specific aspects of colour perception, with some evidence suggesting that these associations follow consistent patterns rather than being wholly arbitrary (in Walker-Andrews (1994) meaning of the term). For instance, one study reported the existence of crossmodal associations between colours and tactile properties such as roughness, softness, viscosity, with rougher textures often linked to darker or more saturated colours (Slobodenyuk *et al.*, 2015). Based on this finding concerning the relationship between colour and touch, another study reported how these associations extend to the amplitude and frequency of vibrotactile stimulation (Yuan *et al.*, 2023). Such findings align with those of a study by Ludwig and Simner (2013) showing that tactile material properties are associated with specific colours; The latter researchers demonstrated that more luminant and higher-chroma colours were associated with smoother and softer stimuli. Additionally, certain colour categories were significantly associated with the smoothest (yellow and white) and roughest (brown and black) materials, and also associated with the softest (yellow and pink) and the hardest (black) materials.

Despite systematic relationships having been reported, some inconsistent results have also been reported in the literature concerning the relationship between tactile material properties and colours. For example, softness was found to be associated with pink and yellow in Ludwig and Simner's (2013) study, whereas it was associated with green in Slobodenyuk *et al.*'s (2015) study. This discrepancy may be attributable to variations in the experimental conditions, or the modality of tactile feedback (pressure, vibration, friction, etc.) that was provided during the experiment. Once again, the suggestion here is that the crossmodal association between tactile material properties and colour is context-dependent. Food evaluation naturally involves the integration of visual colour and tactile information, making food an appropriate research subject in which to explore crossmodal correspondences between colour and touch.

3.4. Visually Perceived Material Properties and the Sensory Incongruency of Foods

While the material properties of natural objects are normally assumed to constitute a congruent Gestalt, integrating multisensory information into a coherent whole, certain materials also provide seemingly incongruent cues to the various senses. Here one might think only of finished marble surfaces, which look streaked and textured (attributable to what is called veining, that is, the natural patterns formed by mineral deposits) yet feels perfectly smooth to the touch (Spence, 2020d). In this case, the initial crossmodal correspondence between visual input and material perception is updated by subsequent haptic feedback, highlighting the adaptive nature of multisensory material perception.

Sensory incongruity in foods is sometimes intentionally created by chefs. Baked Alaska, for example, appears as if it should be hot from its exterior appearance due to the steaming meringue shell but contains ice cream inside. There are some examples where incongruencies between the colour, shape, or texture of a food and its taste result in positive or negative experiences (Velasco *et al.*, 2016). However, the extent to which such incongruencies can modulate the (actual) perceived taste remains largely unexplored. Yeomans *et al.* (2008) showed that a frozen pink smoked salmon dessert looked sweet (due to the colour) but was rated as tasting too salty when eaten (presumably due to a disconfirmation of expectation, with pink ice cream normally being expected to taste sweet and fruity; Piqueras-Fiszman and Spence, 2015). Interestingly, these researchers also reported that this frozen dessert was perceived as saltier when eaten when the food was labelled as ice cream than when labelled as savoury mousse instead.

Category-specific associations (e.g., bitterness and fracturability in chocolate) as mentioned above may initially arise from statistical learning. But over time, through repetitive exposure to shared material structures, these crossmodal associations can develop into statistical crossmodal correspondences that reflect both semantic knowledge and material knowledge that is ecologically grounded as sensory regularities.

3.5. Affectively Mediated Crossmodal Correspondences Involving the Material Properties of Food

Given that incongruent sensory cues can elicit strong affective responses — ranging from surprise and delight to discomfort — it becomes equally important to consider how affective responses are modulated not only by taste or visual expectation but also by tactile material properties. Tactile material attributes, such as smoothness and roughness, play an important role in the associations that have been documented between emotional and sensory perceptions (Etzi *et al.*, 2014, 2016). Tactile stimulation can elicit affective responses in its own right, because touch is intrinsically linked to both pleasant and unpleasant, or potentially threatening, experiences, as well as through learned associations (Gallace and Spence, 2014). In Etzi *et al.*'s (2014) study, a range of common tactile materials (clothes, sandpapers, kitchen supplies) were used to test which materials could be perceived as pleasant on both the hairy and nonhairy skin at a given moving speed of tactile materials. The results revealed that subjective pleasantness was higher when the material was smooth. In addition, when tactile stimulation was delivered using tactile materials at a certain speed (5 cm/s), participants reported that tactile stimulation on hairy skin was more pleasant than tactile stimulation on nonhairy skin, consistent with previous studies. In a subsequent study by the same research group (Etzi *et al.*, 2016), the associations between tactile sensations and people's emotional states were investigated. Tactile textures were presented to the forearm of the participants at a speed of 5 cm/s by the experimenter. The participants rated the intensity of various tactile sensations including perceived smoothness–roughness dimension and evoked given emotions (e.g., happiness, anger, pleasantness, etc.) using a visual analogue scale. Etzi *et al.*'s

(2016) results revealed that tactile materials giving rise to smooth perceptions obtained higher ratings in pleasantness and comfort. Their findings suggest that material properties perceived by touch have hedonic correspondences.

Whether tactile material properties of food evoke affective responses that mediate crossmodal correspondences in taste remains largely underexplored. Slocombe *et al.* (2016) raised a discussion on the influence of hedonic responses evoked by the tangible material properties of food on taste perception. Specifically, they found that foods having a rough surface texture elicited higher ratings of sourness as compared to smooth textures, while no significant effects were observed for sweetness or bitterness. Given that sourness is typically associated with unpleasantness, Slocombe *et al.* (2016) argued that the rough texture may have induced a negative affective response which, in turn, increased the perceived intensity of a negative taste (i.e., sourness). Replication studies are needed to confirm whether the observed crossmodal correspondence happens through affective mediation, as the study did not directly collect any hedonic responses from participants.

3.6. Interim Summary

As highlighted by the research that has been reviewed in this section, crossmodal correspondences involving the material properties of food are shaped by a complex interplay of sensory inputs, including visual, tactile, and auditory cues. These crossmodal correspondences are modulated by material knowledge, learned associations, and affective responses. A material perceived as smooth/rough may evoke pleasant/unpleasant feelings, and these affective values can transfer to other senses, such as odour or audiovisual experiences. Empirical evidence supporting affectively mediated crossmodal correspondence in the context of food remains limited. Some context-dependent effects highlight the complexity and variability of such associations.

4. Does Sensory Impairment Influence Crossmodal Correspondences Involving Material Qualities?

Those individuals suffering from congenital cataracts have been shown not to acquire certain crossmodal correspondences, such as between auditory pitch and felt shape (Hamilton-Fletcher *et al.*, 2018; Sourav *et al.*, 2019). Similarly, Hamilton-Fletcher *et al.* (2018) reported that many early-blind individuals appear to exhibit somewhat different crossmodal correspondences (or else fail to exhibit them altogether) than either late-blind or sighted individuals. These researchers examined whether there was a crossmodal correspondence between five tangible attributes (namely shape, size, weight, texture, and softness) and auditory pitch (namely low or high). Sourav *et al.* (2019) confirmed

Hamilton-Fletcher *et al.*'s (2018) findings, and also identified that those individuals who suffered from some form of visual impairment occurring prior to 12 years of age did not appear to be sensitive to the pitch–shape crossmodal correspondence. Such results indicate that there would appear to be a sensitive period for the acquisition of certain crossmodal correspondences (including those that involve material properties). For whatever reason, specific forms of sensory impairment may also lead to the establishment of other crossmodal correspondences in early-blind individuals such as, for example, the crossmodal association between higher-pitched sound and smoother of softer textures as demonstrated by Hamilton-Fletcher *et al.* (2018).

Those individuals who are sensorially impaired typically use their residual senses in order to make sense of the world around them. For example, it might be expected that the visually impaired would be more sensitive to temperature–material correspondences than the sighted (e.g., to tell whether a brick is black or white simply by sensing its temperature after it has been in the sun, assuming that they had the opportunity to internalize the knowledge that the black objects tend to absorb more heat, and so will likely feel warmer to the touch than white objects; Gonzalez-Crussi, 1989: pp. 26–30). Similarly, when blind individuals use their hands to interact with food, a crossmodal association (or mapping) between touch and taste may occur more readily than in the sighted. For example, a firmer texture in a fruit can be used to assess freshness and the degree of ripeness (Xu *et al.*, 2020), which, in turn, may lead to the estimation of the likely taste of the latter (by contrast, sighted individuals may be more likely to use visual appearance cues for this task instead; cf. Huang *et al.*, 2021). There are also anecdotal reports of blind individuals being encouraged to tell when the onions they are frying are cooked by paying attention to the changing sound that they give off (whereas a sighted individual would presumably use visual translucency and browning as the dominant sensory cue instead; Spence, 2017).

As blind individuals learn the bouba-kiki shape (material attribute) — audio associations without the need for visual information (Graven and Desebrock, 2018) — an association between tactile material perception and other modalities (e.g., sound, or even taste) may also be equivalent between blind and sighted people. Further crossmodal correspondence experiments on material qualities should be conducted with both blind and sighted individuals involved. This would help to clarify whether certain crossmodal correspondences — such as those between texture and sound or taste — can emerge without visual input, suggesting that these correspondences can be rooted in sensorimotor experiences shared by both blind and sighted individuals. Thus far, it also remains an open question as to whether the loss of other senses, such as deafness, would exert a significant effect on the crossmodal associations that are observed, or whether instead vision plays a special role in terms of sustaining crossmodal correspondences (even those that do not obviously involve vision, such as the auditory pitch–elevation correspondence).

5. Conclusions

As made clear by the research that has been reviewed here, crossmodal correspondences involving material properties are undoubtedly relevant to the affective perception of multisensory material quality (what the Japanese refer to as *shitsukan*; Fujisaki, 2020; Komatsu and Goda, 2018; Nishida and Nishino, 2026; Spence, 2020c). To date, such material-based crossmodal correspondences have been studied most extensively in the case of food (i.e., edible materials). For certain foods, a crossmodal correspondence has been documented whereby specific material properties (e.g., glossiness of fish eyes) indicate something about the material quality (e.g., freshness of fish). However, the assumption that there exist universal crossmodal correspondences that apply regardless of the material (or food substrate) under consideration currently remains untested. One of the interesting research directions for the future is therefore to explore material-based crossmodal correspondence using examples of both unprocessed and processed foods, such as raw vegetables, fresh fruits, cooked meals and confectionary snacks. For example, there are a number of reports concerning the general crossmodal correspondence between shape and taste, but this theory may simply not apply, or else apply differently, in the case of unprocessed leafy greens (Spence, 2020a; see Fig. 1).

Recent advances in high-precision 3D food printers allow researchers to produce very different shapes of food stimuli in the same raw material (Derossi *et al.*, 2024; Tagami *et al.*, 2021). Other technological advances in 3D printing technology can also contribute to shape–taste crossmodal correspondences in the context of food (e.g., chocolate; Ogata *et al.*, 2023). The choice of food material is critically important when studying crossmodal correspondences in food *shitsukan*. Chocolate is an ideal foodstuff because as its sweetness and bitterness are widely recognized to vary depending on the cocoa content. On the other hand, shape–taste crossmodal correspondences may be less likely to occur in the case of pasta. People do not expect the shape of pasta to affect its taste, given that its flavour is already established and consistent (and hence its shape properties are entirely arbitrarily related to taste (Hildebrand and Kenedy, 2010). This is another example of context dependency in shape–taste crossmodal correspondences.

In contrast, when the content or flavour of a food item is unknown or ambiguous, material perception may serve as a cue for taste expectation. If so, using extended reality (XR) technology and projection mapping to change the apparent visual texture of the same food from transparent and glossy gummy candy to opaque and matte chocolate will be another promising approach to exploring the impact of visual material perception on taste anticipations, which will contribute to a better understanding of crossmodal correspondence in *shitsukan* on edible materials (see Ueda *et al.*, 2020). A comprehensive survey of material properties that indicate material qualities relevant to human survival, such as freshness and high fat content (i.e., energy density), on the positive side, and avoidance of bitter-tasting or sour-tasting foods (which might be poisonous) on the negative side, for different foods may provide a systematic understanding of crossmodal correspondences in food *shitsukan*.

5.1. AI and the Future of Crossmodal Correspondences in Multisensory Shitsukan Research

Could machine learning be used to increase knowledge concerning currently unidentified crossmodal correspondences involving material properties? There have already been some recent developments in this direction (e.g., see Wenger *et al.*, 2024). Meanwhile, Ward *et al.* (2022) conducted research in which they attempt to predict the existing crossmodal correspondences of odours using an electronic nose. Intriguingly, their study was able to predict the crossmodal associations between shape (visual angularity), pitch (sound), smoothness (tactile texture) and olfactory stimuli, based on physiochemical features of odorants, but was not yet able to predict the perceived pleasantness of odours. The findings of Ward *et al.* (2022) imply that certain crossmodal correspondences (shape angularity, pitch, and texture smoothness) related to odours may not be affectively mediated.

Humans can now use AI, based on known crossmodal correspondences, to predict the temperature of water by analysing the sounds it makes. As described in the Introduction, human listeners can indeed tell the difference between cold and hot liquids. For the temperature discrimination task, repeatedly hearing the sounds of water at different temperatures can facilitate the implicit learning of water temperature from sound, potentially leading to the development of a sound–temperature crossmodal association. Interestingly, Wenger *et al.* (2024) have recently shown that a machine-learning system can also discriminate the temperature of water using only the sounds of water being poured. Note here that previous research in crossmodal correspondences has failed to find the acoustic features that identify the difference between two sounds of pouring water coming from different temperature ranges.

Large Language Models (LLMs) might replace the human participants in crossmodal correspondence experiments. Researchers have already demonstrated that a LLM such as ChatGPT-4 possesses similar crossmodal correspondences as humans. For example, a study by Motoki *et al.* (2024) shows empirically that ChatGPT-4 has a comparable colour/shape–taste crossmodal correspondence as humans in at least three languages (English, Spanish and Japanese). As of March 2026, ChatGPT-5.4 has provided associations between crossmodal sensory descriptors that co-occur in text data. However, these associations do not necessarily demonstrate the existence of material properties and taste crossmodal correspondence in LLMs. Therefore, the significance of studying crossmodal correspondences in humans, as embodied sensory agents, remains intact. After accumulating empirical research on the associations between material properties and taste in individual foodstuffs, it can be expected that these unexplored associations will gradually be integrated into the training data, leading to a state where the impact of material properties on the taste of food can be answered without having to test human participants. As such, looking to the future, food companies may benefit from LLM-based understanding of crossmodal correspondence between material properties and taste, which allows them to predict in advance the taste that consumers expect. While the analysis of chemical compounds in food using machine learning is becoming increasingly accurate in predicting the spectrum of basic tastes experienced by humans (Androutsos *et al.*, 2024), we believe that the contribution of crossmodal correspondence in food *shitsukan* research for estimating expected taste remains significant in food product design for consumer satisfaction.

In conclusion, the principal contributions made by this narrative historical review is first to connect the literature on multisensory *shitsukan* with the growing literature on crossmodal correspondences relevant to the assessment of material properties. The second main contribution is to highlight the possible material dependence of crossmodal correspondences, which can be thought of as another kind of context dependency: put simply, the nature of any shape–taste or colour–taste crossmodal correspondences may always be dependent on the material substrate (either physically present or merely imagined). To date, researchers working on the crossmodal correspondences do not appear to have given sufficient consideration to this important mediating factor, that is, material knowledge, at least in the area of food-based crossmodal correspondences.

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