Crossmodal Compensation:

Sensory Discomfort Affects Consumer Preferences Across Modalities

Abstract

Consumers are frequently exposed to uncomfortable sensory circumstances (e.g., hot weather and noise pollution), yet little research has examined how such discomfort might systematically shape preferences. Drawing from research on crossmodal associations, we propose and empirically support a discomfort-driven crossmodal compensation effect in which consumers exposed to uncomfortable atmospheric sensations in one modality (e.g., loud noise) compensate through product choices across other modalities (e.g., choosing visually “quiet” products). Across five studies, we document the consequences of this phenomenon on actual (studies 1 and 2) and hypothetical (studies 3, 4, and 5) consumer choices and preferences. Further, we demonstrate that a desire to reduce sensory discomfort drives this crossmodal compensation effect, and the spillover only manifests when individuals are unable to adjust within the initially disturbed modality. Our research contributes to the literature on goal theory and crossmodal associations by demonstrating that discomfort experienced in one modality can systematically affect product preferences in other modalities.

Keywords: sensory marketing, sensory perception, crossmodal compensation, crossmodal associations, semantic congruence, crossmodal correspondences, goal-driven behavior

Marketers often attempt to improve customer experiences and boost sales by creating pleasant sensory environments. Indeed, the term *sensory marketing* conjures notions of aroma-filled bakeries, plush hotel carpeting, and violin-accompanied wine tastings. However, consumers frequently make judgments and decisions under less desirable, and even uncomfortable, sensory circumstances. For example, one might stop by a local newsstand on a sweltering hot summer day or peruse department store windows on a frigid winter evening. Similarly, customers in cities often make choices while shopping in the presence of loud traffic sounds or deafening construction noise.

In the current research, supported by the literatures on crossmodal associations and motivational goal theory, we develop a framework to explain when and how consumers faced with uncomfortable sensory exposure in one modality (e.g., audition) may alter their product preferences across other modalities (e.g., vision, olfaction, gustation). In doing so, we make an important contribution to the sensory marketing literature, in which most work has demonstrated assimilation effects in the context of comfortable or neutral sensory inputs. The current work instead examines how consumer discomfort due to exposure to uncomfortable sensory input elicits a contrast effect. Specifically, we propose and empirically demonstrate a novel form of crossmodal compensation in which consumers exposed to uncomfortable sensations in one modality might prefer or choose products with a contrasting association in other modalities. For example, if a consumer is exposed to uncomfortably high temperatures, that individual will want to cool down and thus prefer olfactory, gustatory, or visual products with "cool" perceptual attributes.

Our discomfort-driven crossmodal compensation theory makes a unique contribution to research on multisensory effects by offering a broad framework that systematically applies across modalities and spans multiple product categories, contexts, and crossmodal associations. Whereas extant literature has often focused on singular semantic or metaphorical associations between an abstract concept (e.g., social affiliation) and a perceptual attribute (e.g., warmth), the current work instead links *perceptual attributes across modalities* (e.g., mapping warmth onto scent, sound, flavor, and imagery). Accordingly, this work is the first to demonstrate that discomfort in one sensory modality drives preference for products with the contrasting associations in other modalities. Importantly, we suggest and demonstrate that consumers are likely to prefer products that are crossmodally consistent with their sensory *goals*, and thus contrast with the initial uncomfortable sensation, thereby demonstrating conditions under which contrasting sensory inputs might be preferred. We support this theorizing across five experiments (including two field studies) using actual and hypothetical consumer choices and preferences across a wide variety of products, and establish theoretical and substantive boundary conditions.

Theoretical Framework

An established body of research has demonstrated that sensory cues can have wide-ranging effects on consumer perceptions, judgments, and behaviors (Biswas, 2019; Krishna, 2012). One stream of this research has specifically focused on how environmental cues (i.e., atmospherics; Kotler, 1973; Spence et al., 2014) can influence consumer behavior. For example, ambient music in stores and service settings can affect visual preferences, sales, and visit durations (Biswas et al., 2019; Caldwell & Hibbert, 2002; Klein et al., 2021). Another body of work has examined how the sensory attributes of products can influence consumer responses. A product scent can improve memory for associated information (Krishna et al., 2010) and haptic features of a product can influence judgments of tangential attributes (Ye et al., 2020). However, regardless of whether the source is atmospheric or product-based, features of sensory inputs often carry associations across modalities, as we describe below.

Crossmodal Associations

Although we possess distinct sensory organs (e.g., eyes, ears, etc.) for different senses, many experiences are multisensory by nature, requiring the integration of sensory inputs for perception and decision-making (Driver & Spence, 2000; Senkowski et al., 2008). In line with this integrative view of sensory perception, research has demonstrated that individuals often associate sensory information across the senses (Alvarado et al., 2023; Motoki et al., 2024). In a phenomenon known as *crossmodal correspondence* (Spence, 2011), individuals systematically link features in one sensory modality with features in other sensory modalities. For example, individuals associate high- and low-frequency sounds with light- and dark-colored products, respectively (Hagtvedt & Brasel, 2016). Other researchers have documented crossmodal correspondences between vision and haptics (Motoki et al., 2019), audition and olfaction (Crisinel et al., 2013), audition and gustation (Wang et al., 2020), and gustation and vision (Carvalho & Spence, 2019; Chylinski et al., 2015), among others (see Supporting Information for a selection of additional literature on crossmodal associations).

Individuals also crossmodally link object features that share an identity or meaning — a phenomenon known as *semantic congruence* (Alvarado et al., 2023; Escobar et al., 2023). For example, people associate animals with certain sounds (e.g., dogs and barking; Chen & Spence, 2010), banana scent with the color yellow (Spence & Levitan, 2021), and certain scents acquire a feminine or masculine identity due to their associations with women's and men's products, respectively (Krishna, Elder, et al., 2010).

Several explanations have been put forward as to how these associative links between sensory features are established in the mind (Knöferle & Spence, 2012; Spence, 2011, 2023). Some crossmodal associations stem from our internalization of correlations between stimulus characteristics that exist in the natural environment — for example, small objects tend to emit higher-pitched sounds than large objects, and as a result, we learn over time that these dimensions "go together." Crossmodal associations may also develop linguistically when the same terms are used to describe sensations across modalities (e.g., the word "loud" can describe both sounds and colors, and the words "low" and "high" can refer to both auditory pitch and visual elevation; Gallace & Spence, 2006; Martino & Marks, 1999). Finally, sensory features can obtain semantic meaning due to repeated association with certain experiences (Krishna, Elder, et al., 2010), such as a pine scent and Christmas trees (Spangenberg et al., 2005), and an uncorking sound and champagne bottles (Knöferle et al., 2016).

Due in part to the accessibility of crossmodal associations — whether through crossmodal correspondence or semantic congruency — research has found that, at least in the context of *comfortable*, *positive,* or *neutral* sensory experiences, a match between features of sensory input in one modality with features in a different modality leads to positive consumer outcomes (Imschloss & Kuehnl, 2017; Spence et al., 2014). For example, Krishna and colleagues (2010) found that participants preferred hot and cold therapeutic gel-packs that smelled "warm" (via a pumpkin cinnamon scent) and "cool" (via a sea-island cotton scent), respectively. Such positive effects are usually explained by literature suggesting that when a cue is consistent with expectations, the resulting processing ease (Reber et al., 2004) and subsequent positive affect is transferred to the source of the cue (Fiske, 1982).

However, in everyday life, not all sensations are well-received, and consumers are often exposed to *uncomfortable* sensations. Exploring the influence of these sensations on consumer responses is important, not only because such sensory discomfort is prevalent, but also because it can motivate compensatory behavior and elicit preferences for products with contrasting sensory attributes.

Sensory (Dis)Comfort and Goal-Driven Behavior

Sensory discomfort

We define sensory discomfort as responses to sensory inputs that activate a goal of reducing the specific sensation. There are several circumstances under which consumers might experience uncomfortable sensations. In some instances, a sensory input is fundamentally aversive by nature: some smells from the chemical family of mercaptans (e.g., the odors of decaying vegetation and spoiled milk) are universally considered unpleasant, which may have evolutionarily served a protective purpose (Moncrief, 1970). In other instances, the combination of too many sensory cues can cause consumers to experience sensory overload, leading to negative affect, lower product evaluations, and withdrawal (Doucé & Adams, 2020; Malhotra, 1984; Spence et al., 2014).

Consumers are also likely to find a particular sensory input uncomfortable if it is administered at an overly high intensity, such as hot or cold temperatures and loud sounds. While moderate temperatures are considered pleasant, intense cold or heat leave us shivering or sweating, respectively, and even our favorite music can make us wince if the volume is too high. Indeed, individuals typically seek optimal levels of sensory stimulation (Spence et al., 2014; Steenkamp & Baumgartner, 1992) as part of their desire to maintain a stable internal bodily environment, or homeostasis (Parker & Tavassoli, 2000). For example, one homeostatic process, thermoregulation, drives humans to keep a consistent body temperature (Motoki et al., 2018).

Importantly, decision-making and behavior can help individuals cope with sensory discomfort (Bechara et al., 2000) and maintain homeostasis (Hadi & Block, 2019; Parker & Tavassoli, 2000; Paulus, 2007). Our brains signal pleasure or aversion towards sensory stimuli depending on our internal state and corresponding sensory objectives, and we are accordingly led to make decisions that promote those objectives (Cabanac, 1971; Rolls, 2009). Reactions to undesirable sensory inputs can involve avoidance behaviors (e.g., backing away from the source of an uncomfortable scent or sound) as well as approach behaviors. For example, our brain generates feelings of pleasure toward warm stimuli (e.g., a warm drink) when we feel too cold and pleasure toward cool stimuli (e.g., a cold drink) when we feel too warm (Panksepp, 1988).

Discomfort drives spillover contrast effects

While the literature above demonstrates that individuals are instinctively driven to alleviate sensory discomfort, the sensory inputs themselves are not always under the individual's control. For example, an employee is unlikely to have control over an office thermostat and urbanites do not control the volume of traffic. Importantly, however, goal theory literature posits that the behavioral effects of a goal's activation tend to persist over time until the goal is fulfilled, even if it was activated nonconsciously (Bargh, 2022; Chartrand et al., 2008; Sela & Shiv, 2009). Accordingly, goals may spill over into peripheral domains, leading consumers to compensate with contrasting, alternative behaviors and choices that they do have control over. For example, scholars have shown that physical coldness can activate a need for affiliation, increasing consumer preferences for romantic movies (Hong & Sun, 2012).

Importantly, the literatures on embodiment and conceptual priming reveal the existence of both assimilative and contrasting effects on individuals' judgments and preferences, such that bodily sensations can either increase or decrease the favorability of conceptually consistent objects and activities. Specifically, while comfortable levels of sensory exposure can lead to assimilative judgments and preferences, sensory discomfort can activate goals to "undo" the discomfort, leading to contrasting effects (Förster et al., 2007; Sela & Shiv, 2009; Zhang & Risen, 2014). In other words, the key to determining whether assimilative or contrasting effects are likely to manifest stems from individuals' motivation: When the goal to undo a sensory state is active (inactive), people exhibit contrasting (assimilative) behaviors and preferences (Sela & Shiv, 2009). Zhang and Risen (2014) specifically support this goal systems account in a series of studies on the metaphorical links between physical and social warmth, demonstrating that people primed with a goal to reduce physical coldness seek warmth by preferring socially "warm" activities.

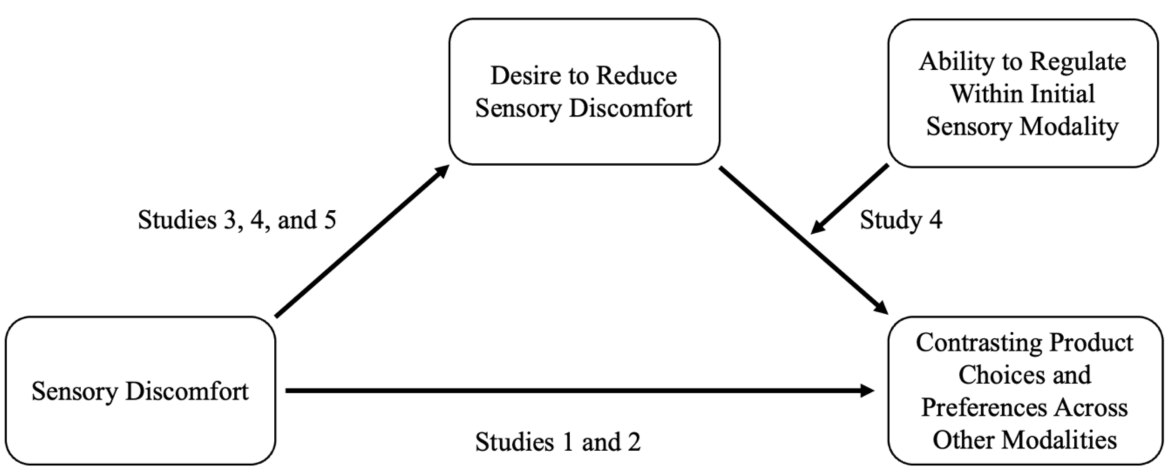
Notably, the aforementioned work focused on a singular metaphorical association between an abstract concept (e.g., social affiliation) and a perceptual attribute (e.g., warmth). We extend such work to the domain of crossmodal associations, which instead link perceptual attributes across modalities (e.g., mapping warmth onto scent, sound, flavor, and imagery). This allows us to present a framework that is not restricted or specific to any singular sensory experience or metaphor, but rather applies across modalities and crossmodal associations.

Discomfort-driven crossmodal compensation

Supported by the literature on crossmodal associations and goal-driven behavior, we propose that goals elicited by sensory discomfort can spill over to product preferences *across sensory modalities*. As mentioned earlier, while much consumer behavior research suggests that consumers prefer products with attributes that match across modalities (e.g., Krishna, Elder, et al., 2010), most of such work has focused on individuals' responses to comfortable or neutral sensations. However, the existence of crossmodal associations implies that if a sensation in one modality (e.g., audition) causes sensory discomfort and a consumer is unable to regulate within that modality, she may alter her product preferences and choices across other modalities (e.g., vision). Specifically, we propose that consumers are likely to prefer products with attributes that are crossmodally consistent with their sensory *goals*, and thus contrast with the sensory properties of the initial discomfort-driving sensation. For example, if an individual is exposed to uncomfortably warm temperature, it will trigger a desire to cool down, and that individual may accordingly display preferences for gustatory and olfactory products with attributes that carry "cool" (vs. "warm") crossmodal associations. This crossmodal compensation should only manifest when a desire to reduce sensory discomfort has been triggered, and when the individual does not have the opportunity to regulate within the modality of the initial discomfort-driving sensation (see Figure 1 for an illustration of our theoretical framework and overview of studies).

Figure 1

Illustration of Crossmodal Compensation Framework



Overview of Studies

We conducted a series of five experiments across two practically relevant sources of sensory discomfort — temperature exposure and auditory exposure — that collectively provide empirical support for our theorizing and framework. First, two outdoor field studies demonstrated that exposure to uncomfortable temperature (either cold or warm) increased individuals' likelihood of choosing a crossmodally contrasting olfactory (study 1) and gustatory (study 2) product. These two field studies are followed by three experiments that extend our investigation by documenting crossmodal compensation in the absence of any semantic cues, and providing empirical support for the assumptions and proposed mechanism in our framework (see Figure 1). Importantly, our studies document both actual (studies 1 and 2) and hypothetical (studies 3, 4, and 5) consumer responses across field and lab settings. Taken together, these studies provide converging support for our discomfort-driven crossmodal compensation effect. All data and materials are available on the Open Science Framework at https://osf.io/tpfxe/.

Study 1

In study 1, we sought to provide initial evidence for our discomfort-driven crossmodal compensation effect under naturalistic conditions. Specifically, we examined how exposure to uncomfortably cold temperature might increase participants' relative preference for a crossmodally "warm" (vs. "cold") product (hereafter referred to as "warm" and "cold" products for brevity). To accomplish this, we took advantage of an unseasonably warm temperature spike on the US East Coast during the winter season and conducted a field study outside a university. This allowed us to minimize any possible effects of seasonality on participants' preferences (e.g., any desire for products associated with certain seasons) and still collect data on two thermally distinct temperature conditions — an uncomfortably cold day and a comfortably warm day — that naturally occurred within a two-week period. We predicted that participants experiencing the uncomfortably cold outdoor temperature would show significantly greater choice likelihood for an olfactorily "warm" product (vanilla-scented lip balm) than an olfactorily "cold" product (peppermint-scented lip balm; see Supporting Information for stimuli selection details) compared to individuals in the comfortably warm temperature condition.

Method

Participants and design

The experimenter stood outside the university entrance between 11:00 a.m. and 12:00 p.m. on an uncomfortably cold day (37°F) and a comfortably warm day (78°F; see Supporting Information for pretest details to determine thermal comfort) holding a sign that read, "Free Lip Balm Courtesy of the Marketing Department." 130 passers-by were offered a free lip balm and asked to choose between two options: vanilla or peppermint. These choices were offered verbally, and the experimenter counterbalanced the order in which the choices were expressed (i.e., "peppermint or vanilla" and "vanilla or peppermint"). The lip balms were concealed in a bag carried by the experimenter so that participants could not make any inferences based on remaining inventory levels. At the end of each day, participants' aggregate choices were calculated based on a count of the remaining inventory.

Results and discussion

Choice of crossmodally warm product

Results of a binary logistic regression with lip balm choice as the outcome variable (peppermint = 0, vanilla = 1) and temperature condition as the predictor variable revealed a significant effect of temperature on product choice ($\beta = -.79$, Wald $\chi^2\,(1) = 4.43$, $p = .035$). The negative coefficient indicates that as predicted, as temperature increased, share for the "warm" lip balm (vanilla) decreased. Those in the uncomfortably cold condition were significantly more likely to choose this "warm" option than those in the comfortably warm condition (61% vs. 41%).

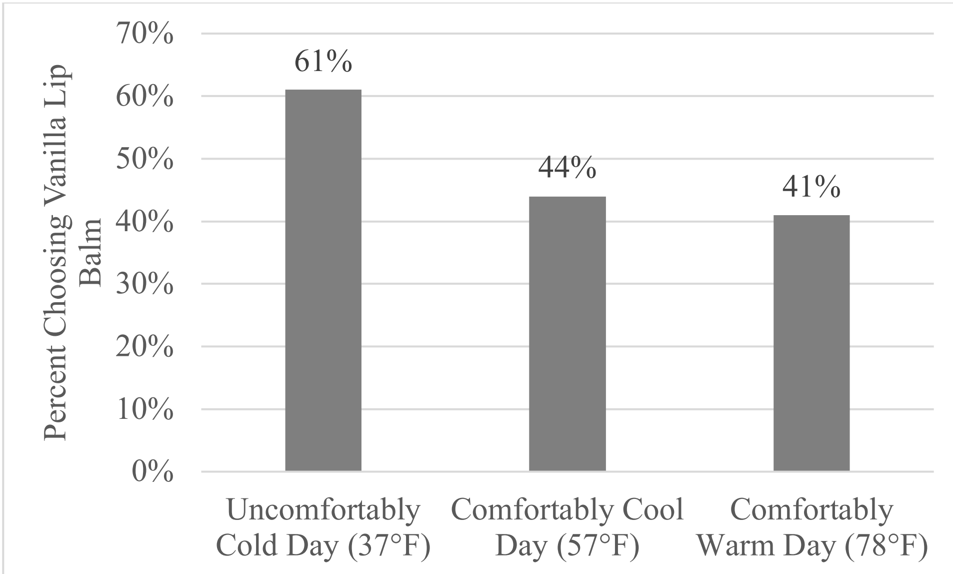
Post-hoc data collection and analysis

While our results support the crossmodal compensation effect, the study design precluded us from ascertaining whether the choice difference was driven by increased desire for the warm product (vanilla) in the uncomfortably cold condition, a decreased desire for vanilla in the comfortable condition, or a combination of the two. Accordingly, we conducted the same data collection procedure with 43 additional participants one month later, on a 57°F day — approximately half-way between the warm and cold condition temperatures (per our pretest results in the Supporting Information, we refer to this as "comfortably cool").

We then reran the binary logistic regression including the additional data. Results with temperature in degrees as the predictor variable revealed a significant effect of temperature on product choice (β = -.02, Wald χ^2 (1) = 4.98, p = .026). An analysis of contrasts revealed a marginally significant difference between the uncomfortably cold vs. comfortably cool 59°F (61% vs. 44%; β = .67, Wald χ^2 (1) = 3.10, p = .078), and no significant difference between the two comfortable conditions (44% vs. 41%; β = .12, Wald χ^2 (1) = .08, p = .784; see figure 2 for an illustration of choice share per day). These results suggest the difference in choice share is not driven by temperature per se, but by thermal discomfort in the uncomfortably cold condition.

Figure 2

Effect of Outdoor Temperature on Choice of "Warm" Olfactory Product (Vanilla Lip Balm)



Study 2

Study 1 allowed us to document the crossmodal effect of uncomfortable cold on real choice behavior within the same season. However, one potential concern is that because the temperature on the warm day was atypical for the time of year, other factors aside from ambient temperature (e.g., overly warm clothing, or mood differences stemming from any atypicality of the weather) may have systematically influenced consumer choices on that day. Accordingly, in study 2 we again explored how exposure to uncomfortable temperature might increase participants' preference for a "warm" (vs. "cold") product, but this time collected the data on four days across three seasons, so that the temperature on each given day was characteristic of the time of year. Importantly, temperature can be considered uncomfortable at both high (hot) and low (cold) levels. Collecting data across a wider range of seasons allowed us to include an extra condition in which the temperature was uncomfortably warm. Further, study 2 extended our findings to a different product category (cookies; see Supporting Information for details about stimuli selection), representing a different sensory modality (gustation).

Method

Participants and design

The procedure was identical to that of study 1; however, we collected data on an uncomfortably cold day in the winter (27°F), a comfortably cool day in the spring (53°F), a comfortably warm day in the early summer (71°F), and an uncomfortably warm day in the late summer (88°F). Instead of choosing between two lip balms, participants in this study chose between two cookies: peppermint (“cold” flavor) or ginger (“warm” flavor) shortbread. 243 passers-by accepted the offer of a free cookie and were asked to choose between the two flavors. We predicted that participants in the uncomfortably cold (warm) condition would show significantly higher (lower) choice share for the gustatorily “warm” product (ginger-flavored cookie) than those in the comfortably cool and comfortably warm temperature conditions.

Results and discussion

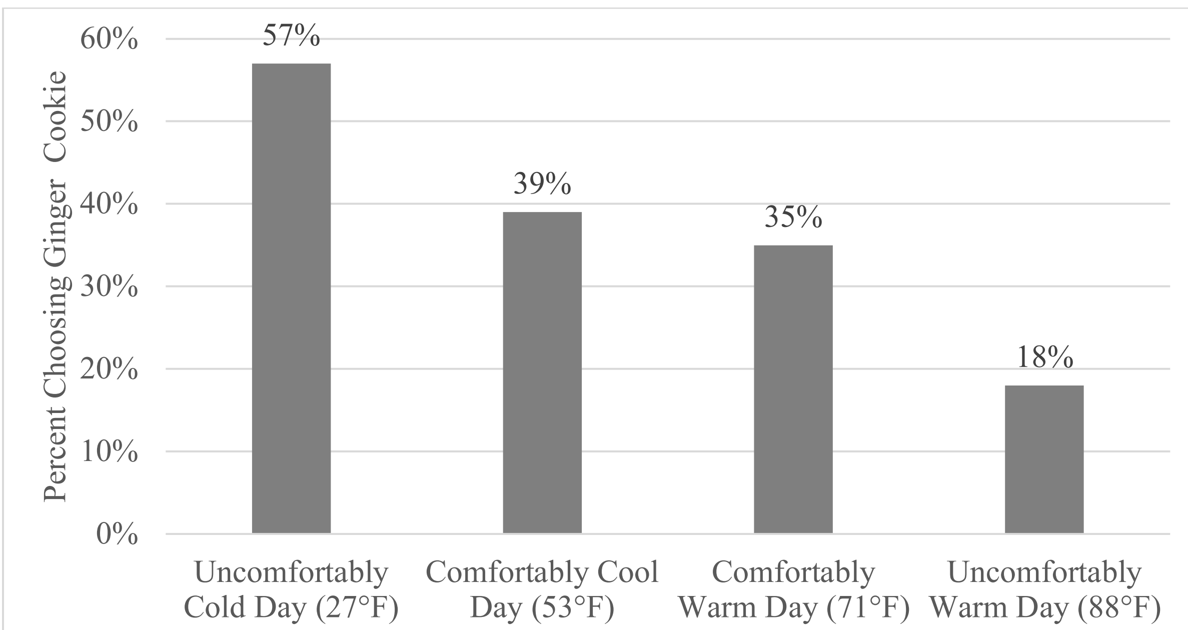
Choice of crossmodally warm product

Results of a binary logistic regression with cookie choice as the outcome variable (peppermint = 0 and ginger = 1) and temperature condition as the predictor variable revealed a significant effect of temperature condition on product choice (Wald χ^2 (3) = 18.99, $p < .001$; see figure 3 for an illustration of choice share per day). An analysis of contrasts revealed that participants in the uncomfortably cold condition chose the ginger-flavored cookie significantly more frequently than those in the comfortably cool (57% vs. 39%, $\beta = -.74$, Wald χ^2 (1) = 3.98, $p = .046$), comfortably warm (57% vs. 35%, $\beta = -.91$, Wald χ^2 (1) = 5.95, $p = .015$) and uncomfortably warm conditions (57% vs. 18%, $\beta = -.80$, Wald χ^2 (1) = 18.48, $p < .001$). Further, participants in the uncomfortably warm condition chose the ginger-flavored cookie significantly less frequently than those in the comfortably cool (18% vs. 39%, $\beta = 1.07$, Wald χ^2 (1) = 6.24, $p = .012$) and comfortably warm conditions (18% vs. 35%, $\beta = .90$, Wald χ^2 (1) = 4.35, $p = .037$).

Consistent with the results of study 1, there was no difference in choice share across the two comfortable temperature conditions (39% vs. 35%, $\beta = -.17$, Wald $\chi^2(1) = 0.20$, $p = .653$), suggesting that choice was not necessarily being driven by temperature per se, but by thermal discomfort more specifically. Overall, these findings replicate those of study 1, suggesting that uncomfortably cold (vs. comfortable) outdoor temperature exposure increases individuals' preference for a "warm" (vs. "cold") product, and that uncomfortable heat works in the opposite direction.

Figure 3

Effect of Outdoor Temperature on Choice of Warm Product (Ginger Cookie)



Together, studies 1 and 2 provide evidence that uncomfortable temperature can affect real choice behavior under naturalistic settings. However, a limitation of these studies is that we did not ask participants to indicate their thermal comfort, and instead relied on pretests to establish differences in thermal comfort across conditions. The next study rectifies this issue by explicitly measuring participants' thermal comfort and by using a different thermal manipulation, thus testing the assumption inherent to our theoretical model that differences in discomfort levels are the impetus for the demonstrated crossmodal compensation effect. In addition, while the product choices in studies 1 and 2 relied on semantic descriptions (i.e., the olfactory and gustatory attributes of the products were described verbally), the remaining studies extend our investigation by documenting consumer responses in the absence of any semantic cues (i.e., participant judgments are based solely on perceptual differences across product attributes).

Study 3

The aim of this preregistered study (https://aspredicted.org/343_BVD) was three-fold. First, instead of providing semantic descriptions of product options, we had participants make a choice based on their individual perceptions of the product options. Specifically, they smelled and chose between two candles that we pre-determined to be olfactorily "warm" and "cool" (see Supporting Information for stimuli selection details), but those descriptors were not provided to participants (i.e., the candles they smelled were labelled as "Candle A" and "Candle B"). Second, we used a manipulation of temperature that allowed us to circumvent any differences in comfort that individuals may experience due to clothing choices. Specifically, we had participants grip either an uncomfortably cold or a neutral stimulus in their hand. We predicted that participants holding the uncomfortably cold stimulus would exhibit a stronger preference for the olfactorily "warm" candle than those in the control condition. Finally, we added an explicit measure of thermal discomfort to provide support for the assumption that differences in discomfort are the impetus for the demonstrated crossmodal compensation effect.

Method

Participants and design

The experiment took place inside a university building on three successive days. The experimenter asked 203 passersby whether they would participate in a marketing experiment on product preferences in exchange for a small gift. In the cold temperature condition, the experimenter scooped two ice cubes out of a cooler in a bag and asked the participant to grip them tightly in his or her hand. In the control condition, the participant gripped plastic, re-usable ice cubes which were at room temperature. While holding the cubes, participants in both conditions were asked to smell two candles, labelled “Candle A” (cinnamon) and “Candle B” (eucalyptus), and to choose which one they preferred at that moment. Immediately afterwards, participants were asked to indicate how comfortable they were on a scale of 1 (very uncomfortable) to 7 (very comfortable). The experimenter noted down these responses on a data collection sheet.

Results and discussion

Choice of crossmodally warm product

A binary logistic regression using candle choice as the outcome variable (eucalyptus = 0 and cinnamon = 1) and temperature condition (0 = control and 1 = cold) as the predictor variable revealed a significant effect of condition on product choice ($\beta = .69$, Wald $\chi^2(1) = 5.21$, $p = .022$). Consistent with our predictions, participants in the cold condition chose the warm-scented (cinnamon) candle significantly more frequently (70.2%) than did participants in the control condition (54.2%).

Next, we sought to test our assumption that it is the discomfort inherent in the thermal sensory input that serves as the impetus for the crossmodal compensation effect. To this end, we conducted a bootstrapping analysis (PROCESS Model 4; Hayes, 2013) based on 10,000 samples in which condition (0 = control, 1 = cold) served as the predictor variable, comfort as the mediator, and candle choice (0 = eucalyptus, 1 = cinnamon) as the dependent variable. As predicted, comfort significantly explained the effect of condition on product choice (indirect effect = .38, 95% CI = .05, .81), while the direct effect was not significant (direct effect = .33, 95% CI = -.33, 1.00). In other words, differences in discomfort did indeed underlie the documented differences in choice likelihood of the warm-scented candle, as per our theorized assumptions.

Taken together, the findings of study 3 replicate those of studies 1 and 2, showing that exposure to uncomfortable sensory stimulation (coldness) increases individuals' preference for a product with contrasting sensory attributes (in this case, a warm-scented candle). Additionally, this study demonstrated that our crossmodal compensation effect is not limited to instances where individuals make decisions based on semantic descriptors, but also manifests when they are exclusively exposed to the sensory properties of products (e.g., the scent of candles). In our next study, we build on these findings by demonstrating that the desire to reduce discomfort mediates the effect of uncomfortable sensory stimulation on product choice. We also explore the moderating role of the ability to regulate the sensory discomfort within the initially disturbed modality.

Study 4

Study 4 served several important purposes. First, it extended our investigation to a different source of sensory discomfort by manipulating the volume of a background noise. Second, we sought to test our full theoretical model (see figure 1) by examining the mediating role of individuals' desire to reduce sensory discomfort. We measured participants' desire to reduce the noise volume, predicting this would explain individuals' relative preference for and choice of visually "quiet" products. Importantly, we contend that the crossmodal compensation effect is most likely to manifest when individuals do not have the opportunity to regulate within the modality of the initial uncomfortable sensory input — only then would we expect the regulatory desire to spill over into alternative modalities. Accordingly, we included an experimental condition in which participants were given the opportunity to regulate within the initially disturbed modality (i.e., by giving them the ability to adjust the background noise volume) to examine if this intramodal regulation would attenuate any effects on crossmodal preferences.

Method

Participants and design

214 undergraduate students participating for course credit (55.6% female, M_{age}= 23.47, *SD* = 5.51) were randomly assigned to one of four laboratory conditions based on a 2(Noise volume: quiet vs. loud) x 2(Adjustment opportunity: absent vs. present) between-subjects design. All participants were given headphones (see Supporting Information for brand and model details) and were asked to listen to an audio track that featured ambient city noises (e.g., traffic). The volume was preset and locked on all computers to be either quiet (20 decibels) or loud (75 decibels; see Supporting Information for details of a pretest to find two volume levels that differed significantly in terms of loudness and comfort). As a cover story, participants were informed before beginning the experiment that they were participating in a study about multi-tasking and would be asked to answer questions while listening to audio on headphones. After putting on the headphones, we measured participants' desire to reduce the volume (our proposed mediator: "I wish I could decrease the volume," "I wish I could increase the volume," [reverse-coded], "The volume of this sound is too loud," and "The volume of this sound is too quiet," [reverse-coded]; all on 7-point Likert scales, α = .84). Afterwards, participants in the adjustment

opportunity condition were asked to raise their hand if they wished to adjust the volume. The lab attendant changed the volume for each participant until he or she was satisfied with the level. Those in the adjustment-absent condition skipped this step. Afterwards, while still listening to the audio, participants were presented with the ten product pairs identified in a pretest as differing significantly in terms of visual "loudness" (see figure 4 for sample pairs and Supporting Information for all pairs and pretest details). For each pair, participants indicated which product they would choose at the current moment. To assess relative preference across each product pair, participants also indicated how desirable they found each product (measured on a 7-point scale anchored by "Extremely undesirable" and "Extremely desirable"). We also included questions that served to test an alternative process based on cognitive depletion — that is, participants in the loud condition may have felt cognitively depleted by the volume, which could have influenced their visual product preferences (see Supporting Information for details of these items and exploratory measures that are not central to the current theorizing). In this and the following study, we also assessed individuals' mood and arousal given that prior research has shown that these can be impacted by sensory stimulation (e.g., Malhotra, 1984) and influence participants' preferences. Specifically, participants indicated their energetic arousal (e.g., active; $\alpha = .81$), tense arousal (e.g., anxious; $\alpha = .86$), and mood (e.g., happy; $\alpha = .87$) on 23 items (Matthews et al., 1990; see Supporting Information for all measures). Then, as a manipulation check, participants indicated how loud (on a 7-point bipolar scale anchored by 1: Very Quiet and 7: Very Loud) and comfortable (on a 7-point bipolar scale anchored by 1: Not at All Comfortable and 7: Very Comfortable) the background noise was at the start of the study. Finally, participants answered an attention check, and indicated their gender and age.

Figure 4

Sample stimuli from studies 3 and 4

Product Category	**Loud Product**	**Quiet Product**
Mug		
Smartphone case		
Luggage Tag		
Notebook		

Results and discussion

Manipulation check and volume adjustment

Eight participants either failed to comply with the experimental instructions (e.g., did not wear their headphones) or failed the attention check, leaving 206 responses for analysis (the predicted interaction and focal contrasts continue to be significant if including these non-complying participants; see Supporting Information). ANOVA results with noise volume and adjustment opportunity as predictors revealed a significant main effect of noise volume on perceived loudness ($F(1, 202) = 548.09$, $p < .001$, $\eta_p^2 = .73$) and comfort ($F(1, 202) = 39.57$, $p < .001$, $\eta_p^2 = .16$), in that those in the loud volume condition indicated the noise had been significantly louder ($M_{\text{Loud}} = 5.68$, $SD = 1.20$ vs. $M_{\text{Quiet}} = 2.16$, $SD = .92$) and less comfortable ($M_{\text{Loud}} = 2.84$, $SD = 1.60$ vs. $M_{\text{Quiet}} = 4.32$, $SD = 1.77$) than did participants in the quiet volume condition. Hence, our volume manipulation was successful. Neither the main effect of adjustment nor the volume x adjustment interaction was significant for either dependent variable (all *p*s > .10).

Further, for those participants given the opportunity to adjust the volume, we coded whether they decreased the volume (-1), left the volume as it was (0), or increased the volume (1). As expected, an ANOVA demonstrated a significant effect of noise volume on the direction of audio adjustment ($F(1, 99) = 16.43$, $p < .001$, $\eta_p^2 = .14$). While those in the quiet volume condition were inclined to leave the volume as is ($M_{\text{Quiet}} = .00$, $SD = .76$), those in the loud volume condition were inclined to decrease the volume ($M_{\text{Loud}} = -.52$, $SD = .50$).

Choice of crossmodally "quiet" products

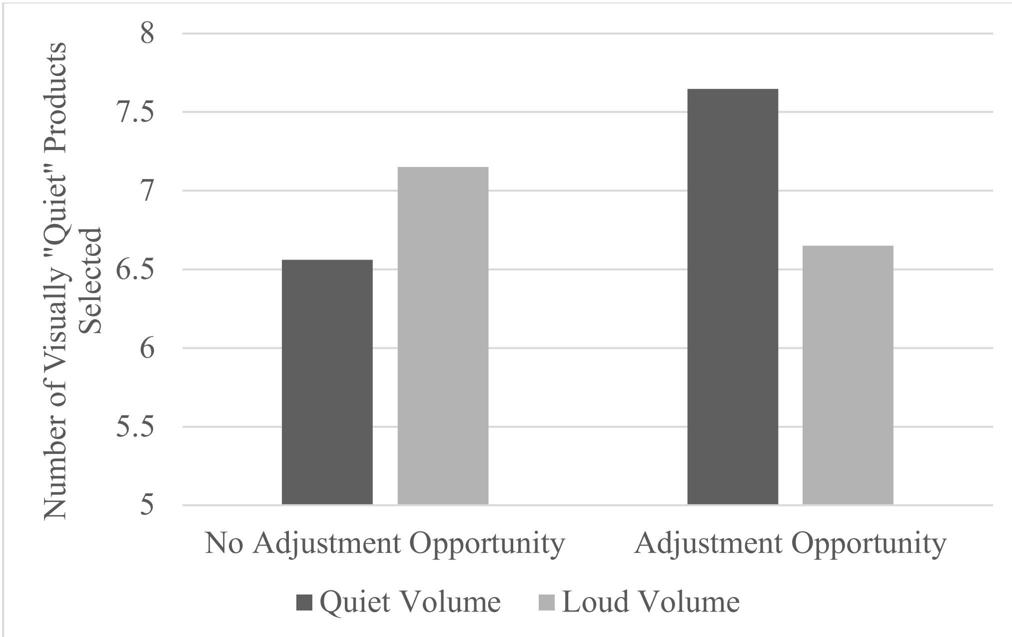
The total number of "quiet" product choices was computed for all individuals. We predicted that when participants were unable to adjust the volume, a loud (vs. quiet) volume would increase their relative choices for visually "quiet" products, but for those with the opportunity to adjust the audio, volume would not influence product choices.

A between-subjects events/trials logistic regression on the number of quiet product choices (out of ten) revealed a significant noise volume x adjustment opportunity interaction (Wald χ^2 (1) = 15.56, $p < .001$). Neither main effect was significant (both *p*s > .12). As predicted, an analysis of contrasts revealed that when there was no opportunity to adjust the audio, participants selected significantly more visually "quiet" products at the loud (vs. quiet) noise volume (M_{Loud} = 7.15, SD = 2.66 vs. M_{Quiet} = 6.56, SD = 2.56; Wald χ^2 (1) = 4.17, p = .041; see figure 5 for an illustration of choice share across conditions). Interestingly, the reverse pattern emerged for participants who did have the opportunity to adjust the audio (M_{Loud} = 6.65, SD = 2.58 vs. M_{Quiet} = 7.65, SD = 2.24; Wald χ^2 (1) = 12.56, p < .001). While this reversal was not hypothesized a priori, it is consistent with previous research suggesting that individuals exhibit assimilation effects in their product preferences when exposed to sensory inputs within a comfortable range (i.e., when they are not motivated to reduce discomfort, which would indeed be the case after adjusting the volume to their liking; we discuss this notion further in the general discussion).

In further support of our theorizing, in the loud volume condition, participants selected marginally significantly more visually "quiet" products when they did not have the opportunity to adjust the volume compared to when they did ($M_{\text{NoAdjustment}}$ = 7.15, SD = 2.66 vs. $M_{\text{Adjustment}}$ = 6.65, SD = 2.58; Wald χ^2 (1) = 3.03, p = .082). Again, though not explicitly hypothesized, the pattern reversed in the quiet condition ($M_{\text{NoAdjustment}}$ = 6.56, SD = 2.56 vs. $M_{\text{Adjustment}}$ = 7.65, SD = 2.24; Wald χ^2 (1) = 14.61, p < .001).

Figure 5

The Effect of Noise Volume and Adjustment Opportunity on Choice of Visually "Quiet" Products



Preference for crossmodally "quiet" products

Participants' relative preference for visually "quiet" products was calculated by subtracting the desirability score of the visually "loud" product from the score of the visually "quiet" product for each category (in line with prior research; Nikolova & Lamberton, 2016; Tully et al., 2015). Higher numbers therefore represented a greater relative preference for visually "quiet" products. We predicted that when participants were unable to adjust the volume, a loud (vs. quiet) volume would increase their relative preference for visually "quiet" products, but for those with the opportunity to adjust the sound, volume would not influence product preferences. To test these predictions, we ran a repeated-measures ANOVA with product category as a within-subjects variable and both volume and adjustment opportunity as between-subjects factors. Mauchley's test indicated that the assumption of sphericity had been violated, and thus results are reported using the Greenhouse-Geisser correction with the corrected degrees of freedom rounded up to whole numbers. The main effects of volume and adjustment opportunity on product preferences were not significant (both *p*s > .72). However, as predicted, the interactive effect of volume and adjustment opportunity on product preference was significant ($F(1, 202) = 7.00$, $p = .009$, $\eta_p^2 = .03$), and this effect did not differ across product categories ($F(8, 1{,}539) = 1.49$, $p = .161$, $\eta_p^2 = .01$; see figure 6 for an illustration of overall mean differences and figure 7 for an illustration of the mean differences for each product across conditions, with the focal contrast in blue). An analysis of contrasts revealed that participants who lacked the opportunity to adjust the volume demonstrated higher relative preference for the visually "quiet" products at the loud (vs. quiet) noise volume ($M_{\text{Loud}} = 1.20$, $SD = 1.59$ vs. $M_{\text{Quiet}} = .62$, $SD = 1.23$; $F(1, 202) = 4.63$, $p = .033$, $\eta_p^2 = .02$). However, for those who had the opportunity to adjust the volume, there was no difference in relative preference across the two volume conditions ($M_{\text{Loud}} = .71$, $SD = 1.49$ vs. $M_{\text{Quiet}} = 1.15$, $SD = 1.12$; $F(1, 202) = 2.54$, $p = .113$, $\eta_p^2 = .01$).

In further support of our theorizing, in the loud volume condition, participants displayed marginally significantly greater relative preference for "quiet" products when they did not have the opportunity to adjust the volume compared to when they did ($F(1, 202) = 3.41$, $p = .066$, $\eta_p^2 = .02$). Though not explicitly hypothesized, this pattern was reversed in the quiet volume condition ($F(1, 202) = 3.59$, $p = .060$, $\eta_p^2 = .02$).

Figure 6

The Effect of Noise Volume and Adjustment Opportunity on Relative Preference for Visually "Quiet" Products

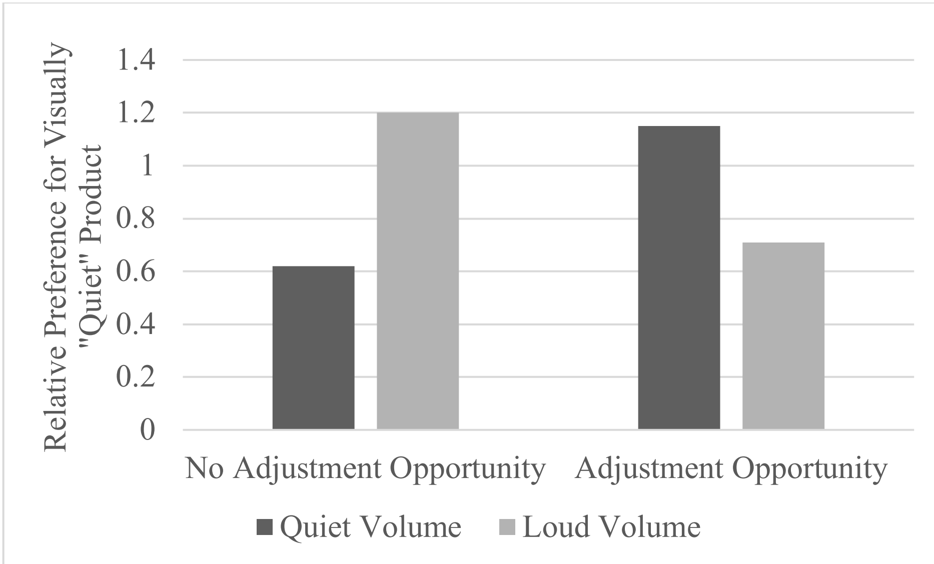
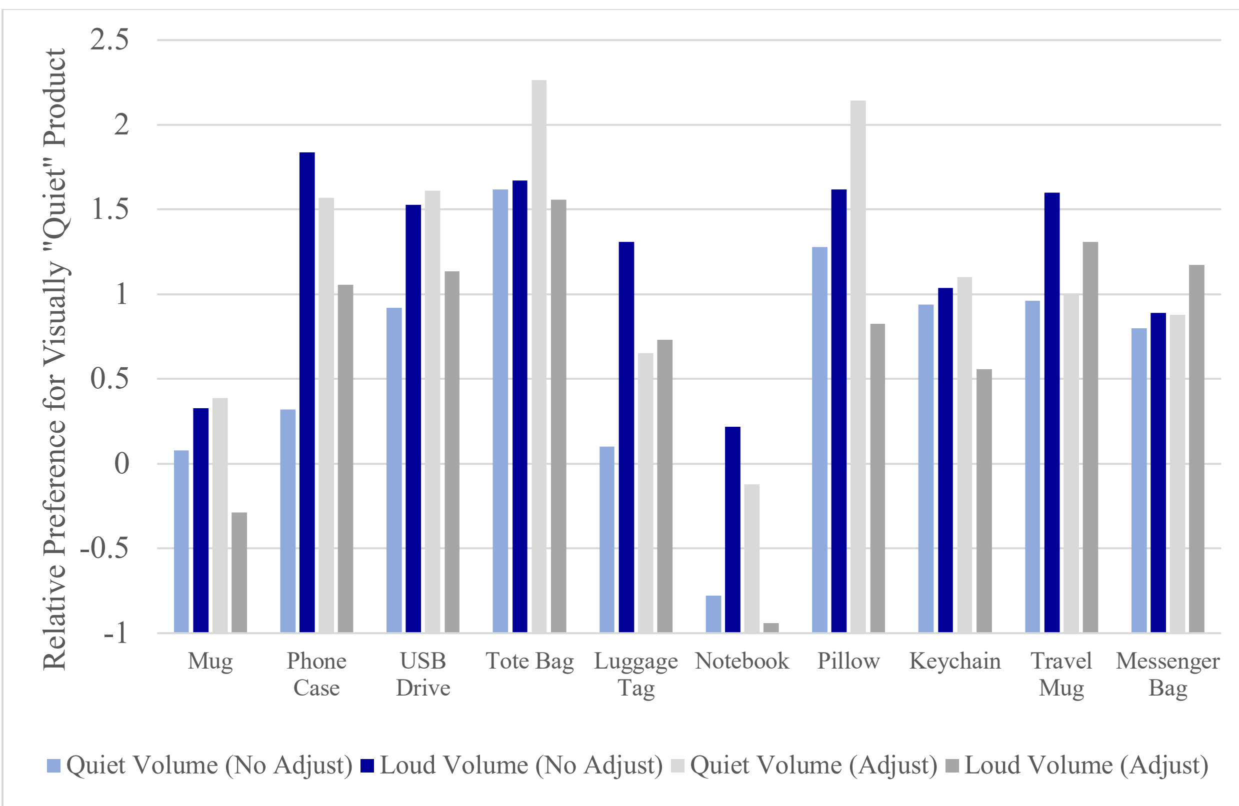


Figure 7

Mean Differences for Each Product Across Conditions in Study 3



Mediation by desire to reduce discomfort

We predicted that while noise volume would exert a main effect on participants' desire to reduce the volume (our proposed mediator), this would only influence relative product preferences for participants who did not have the opportunity to adjust the volume before making their product assessments (i.e., moderation after the mediator; see figure 1). ANOVA results confirmed that the volume manipulation significantly influenced participants' desire to reduce the volume in the predicted direction ($M_{\text{Quiet}} = 3.45$, $SD = 1.21$ vs. $M_{\text{Loud}} = 5.72$, $SD = 1.22$; $F(1, 202) = 177.70$, $p < .001$, $\eta_p^2 = .47$). We performed a moderated mediation analysis based on 10,000 bootstrapped samples (model 15 in Hayes, 2013). Results demonstrated that for individuals who were unable to adjust the volume, the desire to reduce the volume mediated its effect on relative preference for visually "quiet" products (indirect effect = .42, 95% CI = .03, .84). However, for participants who were able to adjust the volume, the indirect effect was not significant (indirect effect = -.28, 95% CI = -.75, .21). The index of moderated mediation was significant (index = -.70, 95% CI = -1.34, -.08), while the direct effect was not significant (index = .01, 95% CI = -.64, .87). These results are in line with our hypotheses, showing that only when consumers lack the ability to adjust within the initially disturbed modality does the desire to reduce discomfort explain the contrasting crossmodal preference. Neither volume, adjustment opportunity, nor their interaction had a significant effect on participants' arousal or mood (see Supporting Information for detailed analyses), suggesting these are unlikely to serve as explanatory mechanisms.

In sum, this study replicated our crossmodal compensation effect in the context of uncomfortable auditory exposure. Importantly, this study provided additional evidence that individuals' desire to reduce sensory discomfort underlies this effect, and addressed alternative explanations involving cognitive depletion, arousal, and mood. In addition, we demonstrated that the effect only manifests when individuals do not have the opportunity to regulate within the modality of the initial sensory discomfort. The next study further supports our proposed process explanation by explicitly manipulating the mediator: individuals' desire to reduce sensory discomfort.

Study 5

The primary purpose of study 5 was to provide additional evidence that the mechanism driving the crossmodal compensation effect is a desire to reduce sensory discomfort. While study 4 supported this process explanation through mediation, in study 5, we wished to support the same mechanism through moderation, demonstrating that the crossmodal contrast effect is weakened when individuals do not have the desire to reduce experienced sensory discomfort. To do so, we adapted a protocol from Zhang and Risen (2014; study 3) by manipulating whether participants had the goal of reducing sensory discomfort or an alternative goal which would not lead participants to want to decrease their discomfort. Specifically, all participants were exposed to the uncomfortably loud background noise from study 3, and we only manipulated whether participants were instructed to reflect on activities to either: a) find relief from the loudness (auditory reduction goal); or b) enjoy their time in a loud city (fun goal). Consistent with Zhang and Risen (2014), we predicted when the alternative (fun) goal was activated, it would reduce the relative preference for visually "quiet" products.

Method

Participants and Design

183 undergraduate students (54.6% female, M_{age}= 22.42, SD = 5.18) participated in this 2-level (Activated Goal: auditory reduction vs. fun) between-subjects study in exchange for monetary compensation. As in study 4, participants were told that the purpose of the study was to

investigate multi-tasking before putting on headphones that played the uncomfortably loud background noise from study 4. Participants then read instructions designed to activate different goals according to their randomly assigned condition (adapted from Zhang and Risen 2014, study 3). Participants in the *auditory reduction goal* [*fun goal*] condition read:

> "It is loud in the city this time of year. Pedestrians, street musicians, and cars fill the street with noise. *Most people want to escape the loud noise after walking around the city for a while [The city offers many fun ways to enjoy the hustle and bustle]*. Please pause a bit and think about what you could do to *find relief from the loudness and achieve some quiet* [*enjoy your time while experiencing the loudness of the city*].
>
> In the three spaces below, please write down three activities that you could do to *find relief from the loudness and achieve some quiet* [*enjoy your time while experiencing the loudness*] in the noisy city."

After the goal manipulation, participants were presented with four pairs of visually quiet/loud products from study 4 (see figure 4) in randomized order. Participants answered the same measures of desirability and choice as in study 4, as well as the same measures of energetic arousal ($\alpha = .82$), tense arousal ($\alpha = .90$), and mood ($\alpha = .85$). Then, as a manipulation check, participants were asked, "When you imagined yourself in the scenario at the start of the study, to what extent were you imagining and listing ways that you could…" and were presented with a 7-point bipolar scale anchored by 1 = "Find relief from the loudness and achieve some quiet" and 7 = "Enjoy your time while experiencing the loudness." Finally, participants answered an attention check, and indicated their gender and age. Analyses of exploratory measures not central to the current theorizing are available in the Supporting Information.

Results and Discussion

Manipulation Check

22 participants either failed to comply with the experimental instructions (e.g., did not complete the manipulation) or failed the attention check, leaving 161 responses for analysis (the pattern of results continues to hold when including these non-complying participants; see Supporting Information). Participants in the fun goal condition indicated that they imagined ways in which they could enjoy their time while experiencing loudness in the city to a greater extent than participants in the auditory reduction goal condition, indicating the manipulation was successful ($M_{\text{Auditory-reduction}} = 3.19$, $SD = 1.98$ vs. $M_{\text{Fun}} = 3.81$, $SD = 1.94$; $F(1, 159) = 4.11$, $p = .044$, $\eta_p^2 = .03$).

Choice of crossmodally "quiet" products

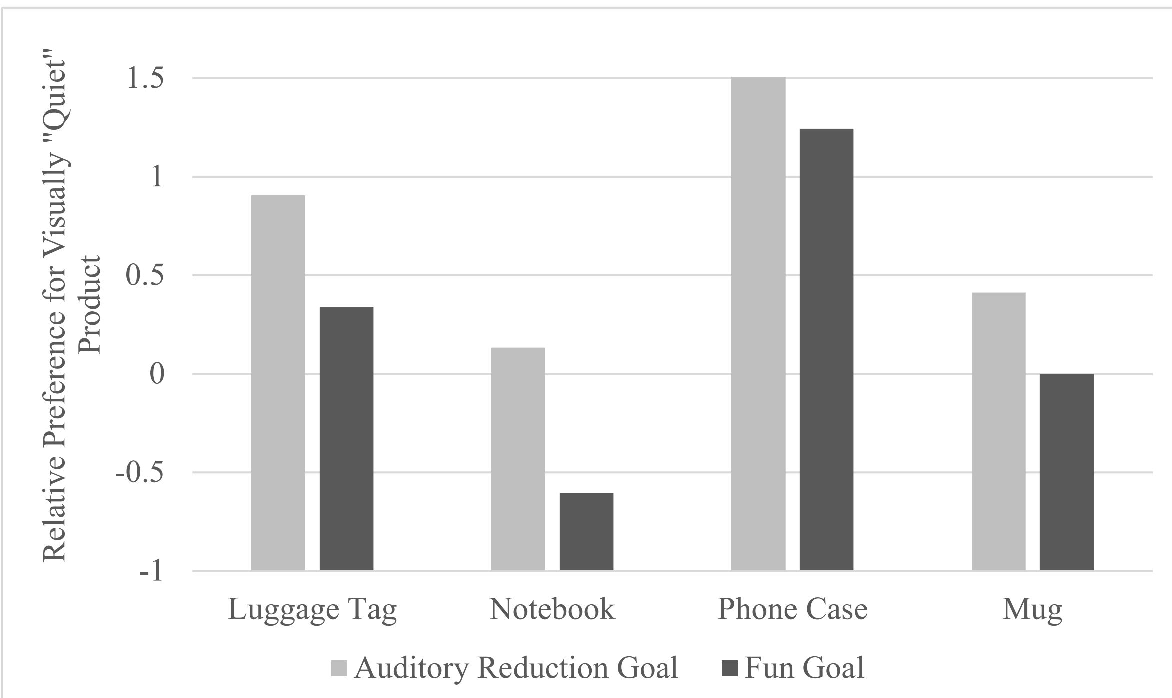
The total number of visually "quiet" product choices was computed for all individuals. We predicted that participants in the auditory reduction goal condition would choose significantly more visually "quiet" products than those in the fun goal condition. A between-subjects events/trials logistic regression on the number of "quiet" product choices (out of four) revealed a significant effect of goal activation (Wald χ^2 (1) = 7.01, $p = .008$). As predicted, those in the auditory reduction goal condition chose significantly more "quiet" products than those in the fun goal condition ($M_{\text{Auditory-reduction}} = 2.65$, $SD = 1.22$ vs. $M_{\text{Fun}} = 2.24$, $SD = 1.38$).

Preference for crossmodally "quiet" products

As in study 3, participants' relative preference for visually "quiet" products was calculated by subtracting the desirability score of the "loud" product from the score of the "quiet" product in each pair. A repeated-measures ANOVA with product category as a within-subjects variable and activated goal as the between-subjects factor confirmed our predictions: participants showed a marginally higher relative preference for visually "quiet" products in the auditory reduction (vs. fun) goal condition ($M_{\text{Auditory-reduction}}$ = .74, *SD* = 1.56 vs. M_{Fun} = .24, *SD* = 1.66; $F(1, 159) = 3.78$, $p = .054$ $\eta_p^2 = .02$; see figure 9 for an illustration of mean differences for each product category across conditions). Notably, this effect did not differ across product categories ($F(3, 477) = .38$, $p = .771$). The goal manipulation did not have a significant effect on participants' arousal or mood (see Supporting Information).

Figure 8

Effect of Goal Activation on Relative Preference for Visually "Quiet" Products



These results provide additional support that the desire to reduce sensory discomfort can explain our crossmodal compensation effect. Specifically, individuals are less likely to exhibit this effect when an alternative goal — different than the desire to reduce sensory discomfort — is activated.

General Discussion

Results from five studies provide evidence for our hypothesis that sensory discomfort in one perceptual modality leads individuals to display contrasting preferences across alternative modalities. Specifically, we find that when consumers experience uncomfortable temperature (studies 1, 2, and 3) and loud noise (studies 4 and 5), they subsequently choose or prefer products that carry contrasting crossmodal associations. Importantly, this effect emerges whether individuals are presented with words to describe products (studies 1 and 2) or actually experience the sensory properties of products (e.g., smelling and seeing the products in studies 3, 4, and 5). We further show that this effect is driven by a desire to reduce the initial sensory discomfort, and only manifests in the absence of opportunities to regulate the aversive experience within the same modality in which the initial perceived discomfort occurs (study 4). Finally, we show that the effect is weakened when individuals lack the desire to reduce sensory discomfort (study 5).

Theoretical implications

Our results contribute to the literature on crossmodal associations, which has established that individuals link features of sensory stimuli across modalities (Alvarado et al. 2023; Motoki et al. 2024; Spence 2011). While much of this research has focused on comfortable sensory experiences and suggests that matching features of sensory input in one modality with features in a different modality leads to positive consumer outcomes, our research documents a crossmodal self-regulatory system that causes a contrast effect, such that sensory discomfort in one modality leads individuals to prefer and seek out stimuli that carry contrasting associations in other modalities. Our work also complements prior findings showing that deviations from a state of balance in a physical state (e.g., reduced thermal warmth) may lead to attempts to restore that balance via embodied representations of that same state (e.g., affiliative warmth; Zhang and Risen 2014). Specifically, we demonstrate that crossmodal compensation is a specific form of isomorphism exploited by the brain, where perceptual attributes are shared *across modalities*. Our research thus offers a generalizable framework that applies across various product categories, contexts, and crossmodal associations, and has theoretical and substantive implications.

The present findings build on recent consumer behavior research that has documented other instances of crossmodal compensation. For example, Biswas and Szocs (2019) found that consumers who experience an indulgent ambient food scent compensate for this rewarding olfactory exposure by making fewer unhealthy food purchases. Rolschau and colleagues (2020) uncovered a similar effect whereby individuals compensated for exposure to a visual packaging cue with sweet perceptual associations (round product typeface) by selecting a beverage with contrasting taste properties (a sour beer). Our research extends these findings by demonstrating that compensatory effects can specifically be prompted by *discomfort*, and are not limited to food products.

The effects obtained in our work cannot be explained by a conceptual or goal priming account. According to this account, conceptual priming increases accessibility of related constructs (Förster et al., 2007), which would lead to assimilation effects — for example, warm temperatures increasing the desire for products associated with warmth. We find the opposite in our studies. The pattern in our work is supported by research suggesting that goal activation — in this case, the goal to decrease uncomfortable sensory exposure — typically induces contrast effects (Sela & Shiv, 2009). Interestingly, study 4 provided some evidence for an assimilation effect when participants were able to regulate the uncomfortable sensory input in the disturbed modality. Specifically, when individuals were able to adjust the sound volume and reduce their discomfort intramodally, they showed a preference reversal, choosing and preferring quiet products more in the "quiet" vs. "loud" volume condition. While we made no a priori prediction for this effect, it is consistent with past research showing assimilation effects that manifest in response to comfortable levels of sensory exposure. In other words, it is likely that since the goal to reduce auditory intensity was no longer active after adjusting the volume, the pattern of effects resembled those that typically follow mere priming (Sela & Shiv, 2009). Future research could further explore the processes driving such assimilation effects.

Managerial implications

Given that consumers are frequently subject to uncomfortable sensory exposure, our research offers various practical implications. For example, during periods of uncomfortably cold weather, marketers would benefit from advertisements featuring "warm" colors and sounds, and brand managers may wish to launch foods and other products with "warm" flavors and scents. The reverse would be true during uncomfortably hot weather periods. Marketers could also take advantage of discomfort in other modalities, such as when consumers in metropolitan areas face uncomfortably bumpy commutes. Our research would suggest that advertisements featured on public transit (or served on the mobile phones of current riders) would be most effective by employing "smooth" sounds and visuals. Beyond serving crossmodally optimized ads, marketers could offer mobile users products and interfaces that crossmodally contrast with their current state. For example, apps and mobile websites might choose to feature "cool" color backgrounds and sounds during times of hot weather, and brand managers might wish to leverage location targeting to offer "smooth"-tasting products on trains and subways.

Indeed, digital innovations in smartphones, beacons, and sensors now give marketers the ability to gauge and respond to consumers' environmental settings in real-time, in a phenomenon known as hyper-contextual targeting (Andrews et al., 2016; Salz, 2015). For example, dynamic billboards can detect weather conditions (Tiffany, 2019), time of day (Jardine, 2018), traffic (Johnson, 2017), and even nearby smoke (Brown, 2017), and automatically change their displays accordingly. These modern technologies could offer the opportunity for real-time responses to these sensory discomforts.

Limitations and Future research

While our investigation was substantively motivated by the question of how consumers might behave in response to sensory discomfort in the marketplace, a theoretical limitation is that we did not definitively categorize the crossmodal associations we examined. That is, we did not disentangle if or when our manipulations were based on a perceptual match between object features across modalities (crossmodal correspondences) or based on product features sharing a common identity (semantic congruency). Future research might extend the findings of the present studies by more closely examining the underlying source of the crossmodal association (e.g., Barbosa Escobar et al., 2023), and exploring whether there are idiosyncrasies in the manifestation of discomfort-driven crossmodal compensation depending on whether this source is semantic congruency or a crossmodal correspondence. Relatedly, across our pretests and experiments, stimuli were sometimes presented with words, and in other cases perceptually experienced (e.g., smelled) without semantic labels. Even when products were evaluated based on their perceptual qualities, however, we did not rule out semantic effects on judgments, or control to which aspect of the stimuli participants attended. Future research could thus also clarify precisely how stimulus features affect responses to the stimuli, and whether semantic or perceptual qualities are evoked.

Future research could also explore individual or contextual differences that modulate responses to sensory discomfort. For example, some individuals are more sensitive to heat and cold and to noise (Zimmer & Ellermeier, 1999). Further, a limitation of studies 1 and 2 is that since these experiments were conducted outdoors, we did not control participants' thermal exposure and thus individuals' clothing may have impacted their comfort levels. Consequently, how warmly or coolly they were dressed may have reflected their sensitivity to the weather, and influenced their product choices. Other traits may also influence individuals' product preferences and the extent to which they prefer products with features that contrast with the initial sensory input. For example, Ranaweera et al. (2021) demonstrated that while many people enjoy a match between haptic features of a product (i.e., texture and weight), those who have a high need for touch may prefer contrasting cues, particularly for exciting brands. Given the various practical applications and future research directions yet to be explored, we hope this work spurs research to build an even more comprehensive account as to when, why, and how atmospheric variables can influence consumer behaviors and product preferences in the marketplace.

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