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Cross-modal Interactions between Color and Texture of Food

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ABSTRACT

Color has a profound influence on human perception. Not only does it cause changes in physiological or emotional states, it can shape what is perceived in other sensory modalities. However, the body of research on these "cross-modal" experiences has predominantly examined color's influence on taste and smell. As such, the aim of this study was to identify the cross-modal influence of color on the sense of touch. In four experiments involving food products, the cross-modal interaction between color and texture was found to be automatic, unlearned, and a moderating effect on perceived texture. Furthermore, results indicate a person's haptic predisposition, or "need for touch," influences their sensitivity to these cross-modal effects. This research builds on current theory involving color, presents a number of areas for future research, and discusses managerial implications of color–texture cross-modal interactions.

> Synaesthesia can best be explained as an exaggeration of cross-modal mechanisms common to us all rather than a privileged, direct pathway ... that is present in synaesthetes but not in others. (Ward, Huckstep, & Tsakanikos, 2006)

On a daily basis, consumers make a large number of decisions about food choices that have both immediate and long-term consequences for their well-being. Many of those decisions use color of the food as a guide to taste and texture. Yet, "despite evidence from studies and real-world examples, marketers know little about the boundary conditions of the effects of altered food colors" (Labrecque, Patrick, & Milne, 2013). In particular, it is not known if consumers obtain a sensory feel of the product through visual inspection of color, or to what extent unexpected food colors such as blue beans or red rice alter that sensory experience (Labrecque, Patrick, & Milne, 2013). Significantly, color is so ubiquitous that it has the ability to profoundly influence perception in other sensory modalities and there is a large body of research (Bellizzi & Hite, 1992; Sagiv & Ward, 2006; Spence & Gallace, 2011) that says this happens in everyday life. When eating a lunch snack, for example, consumers typically view the snack before experiencing its texture in the mouth. Because of this, the color of the snack may affect perceived texture. This effect is referred to as a cross-modal sensory interaction (Spence, 2011), so that the oral somatosensory experience of texture is altered by the prior visual perception of its color.

While some of the cross-modal perception can be attributed to learned or acquired knowledge, Labrecque, Patrick, and Milne (2013) suggest that "the phenomenon of synaesthesia supports the notion that colors have strong biological links to emotions and physical reactions" (p. 192). These cross-modal effects are unique in that a stimulus in one sensory modality (such as vision) is expressed in another modality (i.e., touch). This implies effects of color on processing of nonvisual information such as texture.

This research examines the cross-modal effect of color on perceptions of texture (in the form of oral somatosensory experience) and considers the mediating role a person's "need for touch" (NFT) plays as a link between cross-modal sensitivity and embodied cognition in sensory information processing. Findings from the study indicate not only the two-way interactions between color and actual texture on perceived texture, but also three-way interactions among color, actual texture, and NFT.

The article begins with a review of current literature on color and perception involving the cardinal modalities. In particular, it examines the influence of

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cross-modal color associations on haptic perception. It then outlines the role that a person's haptic predisposition (NFT) plays in their overall sensory sensitivity, and details current research in neurology, psychology, and psychophysics that supports the concept of a "color–touch" cross-modal mechanism. The article then identifies the components and methodology of the study, follows with a discussion on the results and findings, and finishes with the conclusions.

LITERATURE REVIEW AND HYPOTHESES

In its purest form, color might be defined by changes in the light spectrum; characteristics of visual acuity; and the relationships among hue, saturation, and value. But this would be a clinical description that would overlook the role of color in human experience. In fact, a walk through any shopping mall in the world will very quickly highlight the ubiquity, and importance, of color in everyday life. Moreover, it would show that color has the ability to influence both physiological and psychological components of perception and the resultant behaviors. But what is it about color that is responsible for these effects? Research by Crowley (1993) suggests the influence of color occurs as either an activation effect (arousal) or an evaluation effect and that these effects are fundamentally "a function of color wavelength" commonly perceived as hue. This is an important point when looking at research involving color. A review of the literature shows that the broad body of work on colors does incorporate many hues, but there is a general skew toward red and blue as independent variables throughout (Bellizzi & Hite, 1992). As such, many studies compare effects between long-wavelength (red: 700nm) and short-wavelength (blue: 450nm) light. For that reason, and due to their positions at opposite ends of the visual spectrum, this study will focus on red and blue and examine their effects on the human sense of touch.

Psychophysiological Influences of Color

On their own, both red and blue have significant influence over our perception. Typically, red has long been associated with arousal, stimulation, and excitement more than blue (Clarke & Costall, 2008; Wexner, 1954). It follows then that red has also been associated with higher levels of perceived anxiety than blue (Jacobs & Suess, 1975). In research that examined the influence of environmental colors in a retail environment, red was found to be perceived as negative, tense, and physically arousing, while blue was reported as being calm, cool, and positive (Bellizzi & Hite, 1992). It may be that this physical arousal is why red has been found to enhance men's attraction to women (Elliot & Niesta, 2008), or increase performance (and the likelihood of winning) in sporting contests (Hill & Barton, 2005).

Just like color influences psychology, it has a similarly strong influence on physiology. For instance, various studies (Jacobs & Hustmyer, 1974; Wilson, 1966) have used galvanic skin response to show that red is significantly more "arousing" than blue. Red has also been shown to influence human motor functions. Specifically, a red stimulus was found to facilitate both pinch-grip and hand-grip forces (Elliot & Aarts, 2011). Typically, much of the research on touch in consumer settings focuses on cutaneous haptic experience, but this shows an association between color and kinesthetic touch. In addition to these direct physical effects, there exist a number of cross-modal associations whereby color (which is unique to vision) has a profound effect on the other sensory modalities.

Cross-modal Influences of Color

In a study that combined sounds with images of sports cars, it was found that "the sounds heard during the presentation of a red car produced higher loudness ratings," while no other hue reached statistical significance (Menzel, Fastl, Graf, & Hellbrück, 2008). The authors made note of the fact there may be a learned association between sports cars and the color red and that this learned or acquired knowledge may have influenced the results. However, a similar cross-modal association between vision and audition was found when video game players were presented with different colored screens (red/blue) and different sound levels (loud/quiet). Interestingly, the sound levels alone had no significant effect on performance; rather it was the interaction between the sound and color that was associated with changes in perceived excitement and performance (Wolfson & Case, 2000).

In the same way that color influences audition, there appears to be a similar association between color and olfaction. For example, Zellner and Kautz (1990) colored solutions with both appropriate and novel colors and found that odor intensity increased when solutions were colored, as opposed to clear. In a different study, both social drinkers and, to a lesser extent, wine experts reported different perceived aromas when white wine was presented with different amounts of red color (Parr, White, & Heatherbell, 2003). Staying within the chemical senses, the effects of color on taste are even more prolific.

Koch and Koch (2005) found consistent positive relationship between red and sweetness, as well as between red and "fruity." Conversely, red was found to have a negative relationship with sour, bitter, and salty. At the other end of the light spectrum, blue was found to have significant negative associations with tastes including sour, bitter, salty, "citrusy," and "syrupy." Likewise, Lavin and Lawless (1998) showed that, for adults, a change in color (red) saturation has a positive association with the perceived intensity of sweetness. In fact, a review of current literature by Spence, Levitan, Shankar, and Zampini (2010) indicates color is found to have a positive effect on perceived intensity in general. Moreover, the influence of color over taste is so pervasive that the coloring of the food item itself does not need to be manipulated to experience changes in perceived taste. Instead, changes in the color of product packaging (Ares & Deliza, 2010), serving dish (Harrar, Piqueras-Fiszman, & Spence, 2011), the cutlery used to eat the product (Harrar & Spence, 2013), and even the text used to describe product color—such as "dark chocolate" or "milk chocolate"—can result in significant changes of perceived taste (Shankar, Levitan, Prescott, & Spence, 2009).

Given that color is seen to have an effect on both olfaction and gustation, it is natural then to also see the influence of color on flavor identification (Garber, Hyatt, & Starr, 2000) and perceived flavor intensity (Bayarri, Calvo, Costell, & Durán, 2001). This is important for two main reasons. Current literature shows that flavor perception is a product of taste, smell, and oral somatosensation, where all three combine to produce the gustatory experience (Spence et al., 2010). In the first instance, this provides evidence that multisensory, cross-modal associations influence perception on a daily basis. Second, there is a dearth of research that links color to texture so that, even though people might form mental representations of objects that tightly link color to the surface properties of objects (Davidoff, 1991), the question of whether color actually has the ability to influence haptic perception remains unanswered. In a study using vanilla custard, Tom, Barnett, Lew, and Selmants (1987) identified a connection between color and both perceived creaminess and flavor intensity. However, using the Hue, Saturation, Value (HSV) color model as a guide, the design of the study called for manipulations of color value (six different shades from light brown to dark brown) as opposed to hue. In this case, the darker-brown pudding was considered the "most chocolate" and thickest, while the light-brown pudding was considered the "creamiest." In light of the limited research on the topic, it may be necessary to examine the role that texture itself plays in human perception, and whether color and actual texture have any cross-modal interaction that shapes perceived texture.

The Role of Texture and Cross-modal Associations

The concept that perception and cognition are directly influenced by the integration of information from the different sensory modalities is a central tenet of grounded cognition. However, while proponents of grounded or embodied cognition would typically speak of sensory–motor associations (Rosa, 2001; Wilson, 2002), cross-modal aspects of grounded cognition (i.e., the interaction between body sensations and the perceptions of color and texture) remain underexplored. Specifically, the link between hue and perceived texture, compared to other aspects of cross-modal perception, appears to have been overlooked in the extant literature. This is no different in food-related research, where the bulk of research on food appears to focus on relationships between taste and other sensory components (Eertmans, Baeyens, & van den Bergh, 2001). But within the literature that does incorporate different aspects of texture, two key variables reoccur throughout the research—these being creaminess and crunchiness. In a word-association test by Szczesniak (1971), the importance of texture in food consumption was demonstrated when it was mentioned as a product attribute more often than flavor and color. Of the foods used in the study, those that elicited the greatest texture-related responses were ones that were considered crunchy or crisp. In fact, a subsequent study suggested that the terms crunchy and crisp were very similar in meaning, except that a crisp product usually has a "snap" to it (Szczesniak, 1988). By contrast, creaminess is said to be predicted from scores on "smoothness" and "thickness" (Kokini, 1987) and its multisensory appeal is evident in the fact that it is often used to describe flavor, appearance, or texture (Elmore, Heymann, Johnson, & Hewett, 1999). In addition, creaminess has "an intrinsic positive hedonic component" (Frost & Janhoj, 2007) and consumers will typically associate creaminess with "pleasantness" (Antmann, Ares, Salvador, Varela, & Fiszman, 2011).

In this regard, previous research has shown that crunchiness and creaminess may have an inverse relationship to each other. In research that involved changing a food's fat content, it was found that increasing fat content can result in lower sensations of "roughness" or higher sensations of "creaminess" (de Wijk & Prinz, 2005), where "roughness" is used as a proxy for "crunchiness." The obvious result from this is that changing the "actual" texture of the food will cause a corresponding change in the "perceived" texture of the food. In addition, the evidence would suggest that if the color of the food is simultaneously changed, there will be a cross-modal interaction between the color and actual texture that influences perceived texture.

Recent literature indicates that there may be a physiological mechanism underpinning any cross-modal interactions between color and actual texture. In a review of studies that employed various techniques such as fMRI, Kayser and Logothetis (2007) were able to determine that cross-modal interactions between different parts of the brain are commonplace. They point to a range of subcortical nuclei that have the ability to relay cross-modal signals to sensory cortices, and this type of multisensory integration in the neural cortex has also been used to explain the link between color and olfaction (Österbauer et al., 2005). Likewise, research suggests that the primary taste cortex "provides separate and combined representations of the taste, temperature and texture of food in the mouth" (Rolls, 2005). This supports the idea that sensory inputs relating to texture are integrated with sensory information from other modalities. As a result, the following hypothesis is put forward:

H1: Perceived texture will be moderated by a cross-modal interaction between actual texture and color.

Apart from cross-modal integration at a neural level, Ward, Huckstep, and Tsakanikos (2006) suggested cross-modal perception may be due to people using universal cross-modal mechanisms. For example, people typically do not treat vision, texture, and haptic perception as independent experiences (Jones & O'Neil, 1985). As a result, when assessing roughness, or in this case crunchiness or creaminess, no single modality will dominate perception. Rather, "modality appropriateness" regulates the allocation of sensory resources so that the most appropriate modality, or combination of modalities, is employed (Guest & Spence, 2003). In the case of food texture, this will often mean all five cardinal senses are called upon to interpret stimuli. However, what may occur is that one modality will "bias" information from other modalities. Ultimately, the various streams of sensory information are brought into alignment and this modulates "a person's overall (multisensory) product experience" (Spence & Gallace, 2011). Because of this, it is likely that color and texture will interact to create a cross-modal effect that will, in turn, influence perceived texture.

Color–Product Fit

The identification of cross-modal interactions between color and texture would indicate the relationship between these variables is unlearned or developmental, and this fits within the framework for embodied cognition. Typically, this type of automatic response to sensory stimuli was reserved for synesthetes, where cross-modal interactions involving color are not based on memory associations (Ramachandran & Hubbard, 2001). However, recent research (Harrar, Piqueras-Fiszman, & Spence, 2011; Piqueras-Fiszman & Spence, 2012) shows this same level of automaticity is seen across the broader population when cross-modal interactions are involved.

Despite this, Labrecque, Patrick, and Milne (2013) propose a model that suggests, for neurologically normal people, some effects of color also originate from acquired knowledge. If this is so, then not only does the color need to fit the product (Bridle & Timberlake, 1997) it needs to be congruent with various product attributes. This is particularly important for food, where a color that is incongruent with a person's perception of the product has the potential to affect taste (Koch & Koch, 2005), smell (Zellner, Bartoli, & Eckard, 1991), and flavor identification (Garber, Hyatt, & Starr, 2000). Taking this into consideration, a second hypothesis is proposed that allows for an alternate explanation of cross-modal interactions between color and texture. Thus:

H2: Perceived texture will be moderated by the level of perceived fit between product and color.

The use of very different products (in terms of taste, smell, texture, and flavor) throughout the experiments means that subjects may accept the colors (red or blue) as more or less appropriate depending on previous experience. Prior research by Piqueras-Fiszman and Spence (2011) has shown that a person's "differing acquaintance with one brand versus another" will influence cross-modal associations between color (in their case, of the packaging) and product flavor. However, even when this was taken into account, when the color of the packaging was incongruent with the product, subjects were unable to correctly identify the flavor. In relation to the existing study, this same sort of familiarity may be evident with the types of food used, as opposed to specific brands. For example, red or blue custard may appear quite normal, while red or blue mayonnaise may not. As such, testing for the influence of product–color fit will help separate the embodied and referential cross-modal effects of color and provide clearer insight into cross-modal color–texture interactions.

The Cross-modal NFT

To this point, there is a significant body of work that supports the hypothesis on integration of inputs from different sensory modalities. This fits well with Labrecque, Patrick, and Milne's (2013) conceptual model showing the embodied aspects of color associations, levels of automaticity, and the fundamental link to biological responses. Extending this, it may be that a person's predisposition to sensory stimuli will also influence any cross-modal effect between color and texture. Given that texture is an attribute primarily related to the sense of touch, it follows then that a person's haptic predisposition, or their NFT, will be the key indicator.

The NFT scale was developed by Peck and Childers (2003a) to measure a person's preference for haptic information. Their findings showed that individuals differ greatly in the way they interact with objects, how much they touch things, and what their motivations are for touching. Given the different motivations that are shaped by NFT, it has a direct impact on both consumer attitudes and behavior. More importantly, it appears that a person's NFT relates to their overall predisposition for sensory stimuli (Krishna & Morrin, 2008). In the first instance, this means that when people are not allowed to touch a product during the decision process, those that have a high NFT typically have less confidence in their decision (Peck & Childers, 2003a, 2003b). Yet, when they do encounter a setting that includes a touch element, those with a high NFT will experience increased persuasion (Peck & Wiggins, 2006). What is more, the interaction between the haptic element and NFT is so strong that people with high NFT will experience increased persuasion, regardless of their involvement with the message (Peck & Johnson, 2011). In fact, the strength of this interaction is such that the haptic element can be provided by a third-party haptic interface and still create significant responses in the subject. Considering NFT in the context of texture and color interactions indicates an influence of embodied cognition in cross-modal perception. This influence distinguishes embodied cognition from acquired knowledge as a possible enabler of cross-modal effects. As a result, the authors hypothesize the following:

H3: A person's NFT will interact with the cross-modal effect (color × texture), causing a three-way interaction (color × texture × NFT) so that those people who are high NFT will respond more strongly to the cross-modal interaction of color and texture.

Three-way interaction effects with NFT have been shown to exist. For example, high-NFT subjects recorded a three-way interaction (actual touch × quality × NFT) when evaluating a high-quality product (Grohmann, Spangenberg, & Sprott, 2007). Ultimately, though, there are a number of factors driving this interaction process. First, high-NFT people are more aware of sensory stimuli than low-NFT, as well as being more susceptible to affective stimuli (which influence mood) than low-NFT people (Yazdanparast & Spears, 2013). At the same time, color influences people across both psychological and physiological states. These color effects will interact with the actual texture of the product to create a cross-modal effect. As a result, a person's haptic predisposition (NFT) heightens their sensory awareness and sensitivity so that any cross-modal affect will be more pronounced for high-NFT people.

Cross-modal Influences and Marketing Metrics

The managerial implications of cross-modal color and food texture interaction are broad. Product design, packaging, advertising, and point-of-sale are all likely to benefit from findings that increase our understanding of consumer cross-modal perception of color and texture. Not only does haptic sensitivity play a significant role in cross-modal sensitivity, previous research has shown that tactile stimuli contribute to higher-order constructs such as quality, value, and performance. For these reasons, companies are now incorporating tactile features into product specifications. The general argument is that a prepurchase affect, which is triggered by distinctive features such as color, affects perceptions of product experience (Seva, Duh, & Helander, 2007). Because of this, the authors propose that as a person's cross-modal sensitivity increases, their desire for product interaction will increase. In particular, the effects of red versus blue color in relation to haptic sensitivity play an important role in the perception of pleasure, purchase intent, and quality of food products. This presents the following hypotheses:

As color moves from red to blue, pleasure (H4a), purchase intent (H4b), and quality (H4c) will decrease.

The reason is that, while the prepurchase affect may lead to increased purchase intent, current research suggests that haptic stimuli have a positive influence on general feelings of satisfaction and pleasure. Hence, a cross-modal interaction of color and texture that leads to improved perceptions of texture should also affect the marketing metrics in relation to satisfaction and pleasure. In relation to durable consumer products, results of a questionnaire given to car buyers showed subjects reported increased satisfaction when external panels of the car felt harder or stiffer (Rhiu, Ryu, Jin, & Yun, 2011). Similarly, mobile phone companies have been quick to incorporate these concepts, as tactile attributes are high on the consumers' initial wish list for the product (Yun, Han, Hong, & Kim, 2003). Given that these cutaneous, textural encounters increase the pleasure that users experience, it is a logical conclusion that similar pleasure occurs through cross-modal somatosensory stimuli. Typically, blue has been matched with states that are considered more relaxed, more comforting, and more inviting than red. However, the increased arousal and subsequent cross-modal sensitivity that people are likely to experience from red color may alter their orientation. If this happens, their haptic orientation will be more of a hedonic, experiential nature, with less importance being placed on the instrumental, functional nature of their haptic experience. Figure 1

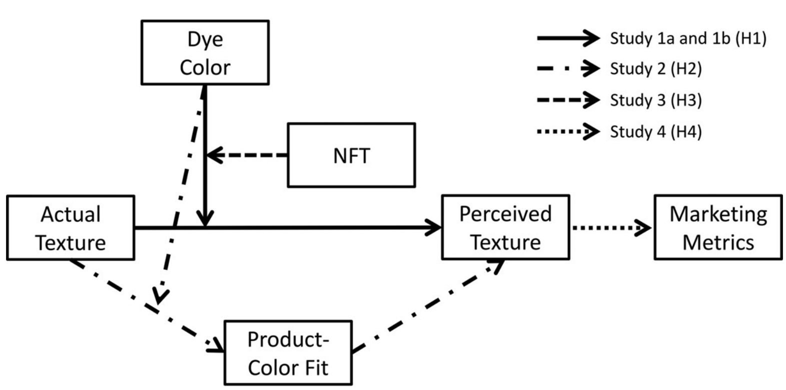

Figure 1. Conceptual model of cross-modal interaction between color and food texture.

shows the conceptual model for the four studies and the related hypotheses.

Given that this study will also be manipulating product textures, the potential change in perceived texture presents an interesting possibility. Current literature would indicate that, of the two food textures to be employed in this study, creaminess, as opposed to crunchiness, is more often matched with the concept of pleasure (Antmann et al., 2011). As a result, it is proposed that the effects of color on pleasure will be mediated via perceptions of creamy texture. Specifically:

> Perceived texture will mediate the effect of color on ratings of pleasure (H4d), purchase intent (H4e), and quality (H4f).

The authors base these expectations on the cross-modal interaction of color and texture, while engaging the person's hedonic, experiential desires. While the hypotheses highlight the mediation effect for pleasure, purchase intent, and quality, it is suspected that the effects on pleasure may be stronger due to the congruence between perceived creaminess and pleasure response. The embodied cognition that occurs as a result of the cross-modal interactions taking place makes people more willing to engage in a pursuit of pleasure than a search for quality. Having proposed the mediation effect of perceived creamy texture, the mediation effect of perceived crunchy texture is also explored. A review of the literature did not reveal a strong argument for a mediation effect between crunchy texture and the three marketing metrics. Nonetheless, for consistency, crunchiness is included in the study to examine its role as a mediator between color and the three marketing metrics.

EXPERIMENTAL RESEARCH

The authors tested the hypotheses in a series of four experiments, where color (red/blue) and texture (creamy/crunchy) were used as independent variables, with perceived texture (creaminess/crunchiness) as the primary dependent variable along with measures for the relevant marketing metrics. NFT was measured as a covariate.

Study 1a: Cross-modal Interaction

The primary purpose of Study 1a was to explore the possibility of the cross-modal effect of color and actual texture on perceived product texture (H1).

Participants. Participants in the experiment were undergraduate and postgraduate students from various schools of a major university. The sample contained data from 128 participants, 47% of whom were female. The mean age of the respondents was 21.9 years (SD = 2.7); ages range from 18 to 31 years. Participants were recruited through the university's research subject pool using ORSEE software (Greiner, 2015) and they received a $10 gift card for their participation.

Procedure. Participants were informed that a new variety of lunch snacks were being considered and were invited to try these snacks, as well as answer a few survey questions about the snacks. The study was conducted in a dedicated computer experimental laboratory at the university. The ingredients for the snacks were chosen and prepared by a food scientist at the university, and subjects were screened for potential food allergies, sinus, or taste problems.[1] Before tasting the snack, participants took a bite of a dry cracker and drink of water. Each participant then tasted the snack. The snacks were set on standard white plastic spoons to the left of the computer screen. Instructions on the computer screen (administered via the Qualtrics online survey tool—www.qualtrics.com) directed participants to try the snack and then to answer a set of survey questions about that snack.

Experimental manipulations: A between-subject factorial design manipulated the 2 (texture: creamy vs. crunchy) $\times$ 2 (color: red vs. blue) for a single product type: light yogurt with almonds. The creamy texture condition was created by mixing a creamy base (light yogurt) with a low amount of crunchy flakes (almonds). Matching the creamy base with a high amount of the crunchy flakes created the crunchy texture condition. The color conditions were created by mixing a standard amount of red or blue food dye with the creamy base at a ratio of 19 ml of color per 1 kg. The full ingredient list is provided in the Table A1.

Participants were randomly assigned to one of the four experimental conditions, creamy/red (n = 34), creamy/blue (n = 35), crunchy/red (n = 30), and crunchy/blue (n = 29). Sessions scheduled 36 participants at a time, which is the capacity of the laboratory. On arrival, each participant filled out a consent form and agreed to participate on the condition of no food allergies, sinus, or taste problems. Participants dismissed from the experiment due to any of these concerns were awarded $5 show-up fee. Eligible participants would begin the experiment at the same time, followed instructions, and answered questions on the computer screen at their own pace. All instructions, questions, and responses were handled using the Qualtrics online survey. Once all participants finished, they were debriefed and dismissed together; the laboratory was then prepared for the next session. The average duration of the experiment was 25 minutes with 30-minute preparation time between the sessions.

Measures. After eating each snack, participants were asked a number of preliminary questions to determine the perceived flavor (taste, smell, texture); and the perceived color of the snacks. To measure perceived taste, participants described the taste in their own words and

[1] The authors adapted the tasting procedure used by Lavin and Lawless (1998).

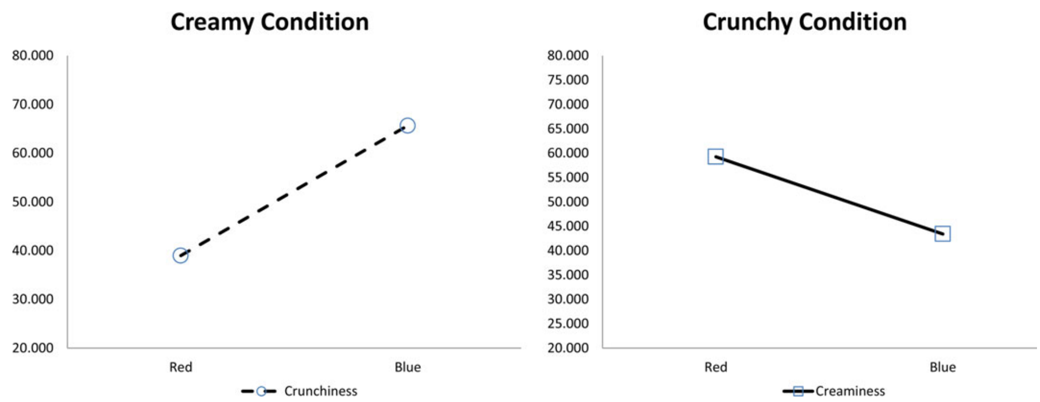

Figure 2. Cross-modal effect of color on perception of food texture (Study 1a).

rated its intensity using a slider on a 0-to–100 scale, where 0 was anchored as "not at all" and 100 as "extremely." All intensity ratings used the same scale. Participants then rated the intensity of the four primary tastes salty, sweet, bitter, and sour as identified by Silverthorn and Johnson (2010). To measure smell, participants described the smell in their own words and rated its intensity. Since no standard aspects of smell are agreed in the literature (Rozin, 1982), participants were asked to rate the intensity of smell relative to ingredients in our snacks (milky, vanilla, egg, sour cream, nutty, and chocolate). To measure perceived texture, participants described the texture in their own words and rated its intensity. They then rated the intensity of hard, soft, oily, watery, and gummy aspects of the texture (Bourne, 2002; Rosenthal, 1999).

To measure perceived color, participants described the color of each snack in their own words and rated its intensity. They then rated the intensity of red and the intensity of blue color for the snack.

Dependent variables: To examine the effect of color on perceived texture, participants rated perceived intensity of creaminess and the intensity of crunchiness for the snack.

Results. Manipulation Checks: Table A2 summarizes the results of the multivariate general linear model (GLM) run on the perceived aspects of flavor. The results reveal significant differences between the two snacks in line with the ingredients used in each snack. Generalized linear model (GLMM) run on the perceived intensity of crunchiness (creamy texture condition = 52.55, crunchy texture condition = 70.34, $F(1, 111) = 14.24$, $p < 0.001$) and perceived intensity of creaminess (creamy texture condition = 55.40, crunchy texture condition = 51.47, $F(1, 111) = 0.97$, $p > 0.10$) of snacks reveals significant main effect of the texture condition for the crunchiness but not for the creaminess measure. This result is explained by the manipulation where the creamy base (light yogurt) was held constant while the amount of crunchy flakes (almonds) varied to affect the texture. GLM run on the perceived red color (red dye condition = 58.56, blue dye condition = 6.98, $F(1, 111) = 563.82$, $p < 0.001$) and perceived blue color (red dye condition = 4.76, blue dye condition = 65.91, $F(1, 111) = 733.32$, $p < 0.001$) of snacks reveals significant main effect of the color condition based on both these measures.

Cross-modal Effect: Study 1a aimed to demonstrate the cross-modal effect of color and actual texture on perceived texture, using a light yogurt and almonds product. A random intercept GLMM using standardized variables revealed a statistically significant interaction between color and actual texture for measures of perceived crunchiness ($\beta = -0.19$, $F(1, 109) = 5.24$, $p < 0.05$), while only a marginal effect was observed for the perceived creaminess measure ($\beta = -0.16$, $F(1, 109) = 2.88$, $p < 0.10$; see Table 1). Analyzing the conditional effect for different texture conditions (model 1; Hayes, 2012) suggested that color affected perceptions of crunchiness in the creamy texture conditions (Effect = 0.51, $t = 4.23$, $p < 0.001$); while in the crunchy conditions color affected perceptions of creaminess (Effect = –0.31, $t = -2.42$, $p < 0.05$).

Specifically, in the creamy condition, changing color from red to blue increased the perception of crunchiness (MD = 26.68, $t = 4.23$, $p < 0.001$). In the crunchy condition, changing color from red to blue reduced the perception of creaminess (MD = –15.85, $t = 2.42$, $p < 0.05$). See Figure 2. These results are in line with the expectation in H1.

Discussion. Study 1a demonstrates the cross-modal interaction of color and texture on perceived texture. Compared to red, the blue color was associated with greater perception of crunchiness when the product was creamier (light yogurt with minimal crunchy almond flakes). In contrast, when the amount of the crunch flakes was high (the crunchy condition) the blue color was associated with reduced perception of creaminess. These results provide the first indication of a cross-modal (vision $\times$ texture) processing of somatosensory experience. However, while they are in line with the expected direction of the effect, it would appear the

Table 1. Results from the GLMM Analysis for Studies 1a, 1b, 2, and 3.

	Perceived Creaminess				Perceived Crunchiness			
Study	1a	1b	2	3	1a	1b	2	3
Intercept	0.00 (0.69)	−0.18 (0.61)	−0.02 (0.70)	0.40 (0.68)	0.00 (0.63)	0.23 (0.65)	0.00 (0.66)	−0.08 (0.70)
Color	−0.16* (0.09)	−0.15 (0.08)	−0.10 (0.07)	−0.01 (0.06)	0.031*** (0.08)	0.12 (0.08)	0.16** (0.07)	−0.08*** (0.03)
Texture	−0.09 (0.09)	−0.65*** (0.08)	−0.09 (0.07)	−0.51*** (0.06)	0.34*** (0.08)	−0.134 (0.08)	0.19*** (0.07)	0.13*** (0.03)
Color × texture	−0.16* (0.09)	0.10 (0.08)	0.18*** (0.07)	0.13*** (0.03)	−0.19*** (0.08)	−0.07 (0.08)	−0.03 (0.07)	0.05 (0.03)
Product			0.05 (0.07)				0.31*** (0.07)	
Color × product			−0.06 (0.07)				−0.02 (0.07)	
Texture × product			0.00 (0.07)				0.02 (0.07)	
Color × texture × product			0.03 (0.07)				−0.12 (0.07)	
NFT				−0.15*** (0.05)				−0.03 (0.04)
Color × NFT				0.00 (0.05)				0.02 (0.05)
Texture × NFT				0.04 (0.05)				−0.02 (0.05)
Color × Texture × NFT				−0.095** (0.045)				−0.07 (0.05)

* .05; ** .01; *** .001.

salience of the two product ingredients (creamy base and crunchy almond flakes) has an influence on the overall cross-modal effect. To explore this effect further, the authors chose to run Study 1b, where they repeated experiment 1a with a creamier base product. The expectation was that the dominant creamy base would focus participants' attention on perceptions of creaminess rather than crunchiness.

Study 1b: Cross-modal Interactions and Attribute Salience

The purpose of Study 1b was to investigate the cross-modal effect proposed in H1 but with a creamier product. By repeating the study with a creamier product the experiment hopes to introduce the creaminess as the dominant texture. With creaminess as a more salient attribute, it is expected that the change in color from red to blue will result in a reduction in perceived creaminess for the overall product.

Participants. Participants in the experiment were undergraduate and postgraduate students from various schools of a major university. The sample contained data from 123 participants, 60.2% of whom were women. The mean age of the respondents was 21.8 years (SD = 3.1); ages range from 18 to 31 years. Participants were recruited through the university's research subject pool using ORSEE software and received a $10 gift card in return for their participation.

Procedure. A between-subject factorial design manipulated the 2 (texture: creamy vs. crunchy) × 2 (color: red vs. blue) for a single product type: full-cream yogurt with muesli. The creamy texture condition was created by mixing a creamy base (full-cream yogurt) with a low amount of crunchy flakes (muesli). Participants were randomly assigned to one of the four resulting experimental conditions: creamy/red (n = 31), creamy/blue (n = 31), crunchy/red (n = 30), and crunchy/blue (n = 31). The full ingredient list is provided in the Table A1. Further procedure and measures were identical to those in Study 1a.

Results. Manipulation Checks: First, manipulation checks were taken for the aspects of flavor, texture (creaminess vs. crunchiness) and color (red dye vs. blue dye) of the snacks. Table A2 summarizes the results of the multivariate GLM run on the perceived aspects of flavor. The results reveal significant differences between the conditions, in line with the ingredients used in each snack. GLMM run on the perceived intensity of crunchiness (creamy texture condition = 40.39, crunchy texture condition = 32.77, $F(1, 121) = 2.72$, $p > 0.10$) and creaminess (creamy texture condition = 66.48, crunchy texture condition = 28.31, $F(1, 121) = 67.04$, $p < 0.001$) of snacks reveals significant main effect of the texture condition on the creaminess but not the crunchiness measure. In contrast to Study 1a, this

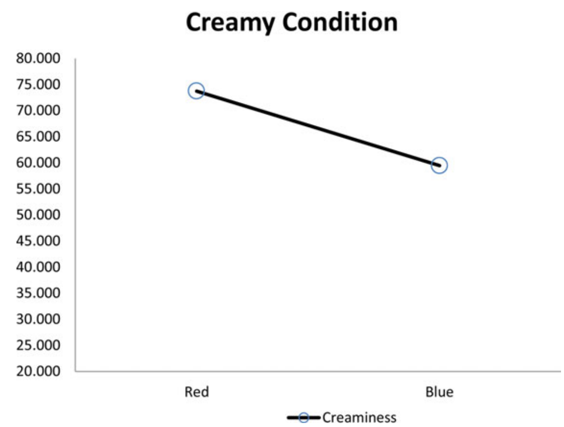

Figure 3. Cross-modal effect of color on perception of food texture (Study 1b).

result reflects the expected dominance of the creamy base (full-cream yogurt). GLM run on the perceived red color (red dye condition = 61.07, blue dye condition = 5.90, $F(1, 121) = 629.40$, $p < 0.001$) and perceived blue color (red dye condition = 8.13, blue dye condition = 70.87, $F(1, 121) = 506.432$, $p < 0.001$) of snacks reveals significant main effect of the color condition based on both these measures.

Cross-modal Effect: Study 1b aimed to demonstrate the cross-modal effect of color and actual texture on perceived texture, using a full-cream yogurt with muesli product. A random intercept GLMM using standardized variables did not reveal overall statistically significant interactions between color and texture for either creaminess or the crunchiness measures (see Table 1). Nonetheless, analyzing the conditional effect for different texture conditions (model 1; according to Hayes, 2012) indicates that color significantly affected perceptions of creaminess in the creamy product conditions (Effect = –0.242, $t = 2.183$, $p < 0.05$).

Specifically, in the creamy condition, changing color from red to blue reduced the perception of creaminess (MD = –14.282, $t = 2.787$, $p < 0.01$). This result is in line with the expectation in H1. See Figure 3.

Discussion. It seems creaminess judgments respond to color manipulations, but the measure on which participants respond follows the dominant texture of the product. Since product type may influence how participants react to the perceptions of texture, it is possible that the results could be very different if different products were used.

Repeating the experiment with a full-cream (instead of light) yogurt and muesli flakes (instead of almonds) resulted in a much creamier overall product than in Study 1a. Given the dominance of the creamy texture, the blue color, in comparison to red, resulted in reduced perceptions of creaminess (rather than an increase in perceived crunchiness as in Study 1a) in the low-crunchy condition. This effect implies that the exact manner in which the cross-modal effect is expressed might depend on the type of product.

Study 2: Color–Product Fit

Studies 1a and 1b demonstrated the existence of a cross-modal effect between color and actual texture, which influences perceived texture. However, to account for the possibility that some product types may be better suited to the red and blue manipulation than others, the goal of Study 2 was to explore H1 under the boundary condition of color and product fit. To check the extent to which this fit affects conclusions about H1, Study 2 increased the fit contrast by using two new products: (1) a custard-based product, which in the pretests was found to suit the red or blue color, and (2) a mayonnaise-based product, which in the pretests tested as unusual for the red or blue color.

Participants. Participants in the experiment were undergraduate and postgraduate students from various schools of a major university. The Study 2 sample contained data from 205 participants, 55.8% of whom were female. The mean age of the respondents was 22 years (SD = 3.2); ages range from 18 to 39 years. Participants were recruited through the university's research subject pool using ORSEE software and subjects received a $10 gift card in return for their participation.

Procedure. The experiment was a 2 (texture: creamy vs. crunchy) × 2 (color: red vs. blue) × 2 (product type: chocolate flakes with custard versus pine-nuts with mayonnaise) between-subject factorial design. Allowing for the two products, participants were randomly assigned to one of the eight resulting experimental conditions: custard (creamy/red [$n = 27$], creamy/blue [$n = 19$], crunchy/red [$n = 30$], and crunchy/blue [$n = 29$]) and mayonnaise (creamy/red [$n = 24$], creamy/blue [$n = 16$], crunchy/red [$n = 29$], and crunchy/blue [$n = 31$]). The procedure was the same as the previous studies in all other respects. The full ingredient list is provided in the Table A1.

Measures. In addition to the measures used in the above studies, study 2 also measured perceived fit of color with product. The "Color Appropriateness" scale developed by Bottomley and Doyle (2006) was used, whereby subjects were asked to rate, on an 11-point scale with anchors at 1 (highly inappropriate) and 11 (highly appropriate), how suitable the color was in relation to the product.

Results. Manipulation Checks: First, manipulation checks were taken for the aspects of flavor, texture (creaminess vs. crunchiness) and the color (red dye vs. blue dye) of the snacks. Table A2 summarizes the results of the multivariate GLM run on the perceived aspects of flavor. The results reveal significant differences between the two snacks in line with the ingredients used in each snack. GLMM run on the perceived intensity of crunchiness (creamy texture condition = 34.16, crunchy texture condition = 45.99, $F(1, 206) = 10.08$, $p < 0.01$) and creaminess (creamy texture condition = 70.83, crunchy texture condition = 65.34, $F(1, 206) = 2.33$, $p > 0.10$) of snacks reveals significant main effect of the texture condition on the crunchiness but not on the creaminess measure. The result is explained by the manipulation where the creamy base was held constant while the amount of crunchy flakes was varied to affect the texture. GLM run on the perceived red color (red dye condition = 70.53, blue dye condition = 9.40, $F(1, 206) = 643.72$, $p < 0.001$) and perceived blue color (red dye condition = 7.50, blue dye condition = 76.17, $F(1, 206) = 818.87$, $p < 0.001$) of snacks reveals significant main effect of the color condition based on both these measures. GLM also indicated a significant effect of product type on perceived product fit ($F(1, 206) = 16.182$, $p < 0.001$) suggesting that the custard and the mayonnaise products were perceived differently in terms color and product fit.

Cross-modal Effect: First, Study 2 aimed to replicate the cross-modal effect of color and actual texture on perceived texture using the custard- and mayonnaise-based products. A random intercept GLMM using standardized variables revealed a statistically significant interaction between color and texture for measures of perceived creaminess only ($\beta = 0.18$, $F(1, 200) = 6.79$, $p < 0.01$; see Table 1). Specifically, in the creamy condition, changing color from red to blue reduced the perception of creaminess (MD = –16.31, $t = 2.94$, $p < 0.01$) but it also increased perceptions of crunchiness (MD = 10.88, $t = 2.00$, $p < 0.05$). This result is in line with expectations in H1, and the results observed in Studies 1a and 1b.

Fit with Product Type: However, the main objective of study 2 was to test whether the cross-modal effect in H1 depends on the fit of color with the product type. GLMM analysis looking at the interaction of the cross-modal effect (i.e., color × texture) with the product type revealed no statistically significant effect for perceptions of creaminess ($\beta = 0.03$, $F(1, 200) = 0.22$, $p > 0.10$), and a marginally significant effect for perceptions of crunchiness ($\beta = -0.12$, $F(1, 200) = 3.34$, $p = 0.069$). Investigating further, a moderated mediation test (model 7; according to Hayes, 2012) using the perceived product and color fit as the mediator between the cross modal effect (color × texture) and perceptions of texture (creaminess or crunchiness), while keeping product type as the moderating variable, revealed no significant mediation or indirect conditional effects. However, a conditional direct effect was noted, such that the cross-modal perceptions of creaminess were significant for the mayonnaise-based product (Effect = 0.20, $t = 1.97$, $p < 0.05$) but not for the custard-based product (Effect = 0.16, $t = 1.619$, $p > 0.10$). The means analysis further revealed that changing color from red to blue reduced perceptions of creaminess in the creamy condition for the mayonnaise product (MD = –21.17, $t = 2.60$, $p < 0.01$). In the case of the custard product, the effect did not reach statistical significance (MD = –11.452, $t = 1.516$, $p > 0.10$). Similarly, perceptions of crunchiness in the creamy condition increased for the mayonnaise product (MD = 17.625, $t = 2.184$, $p < 0.05$), but did not reach significance for the custard product (MD = 4.138, $t = 0.553$, $p > 0.10$). By contrast, in the crunchy condition, perceptions of crunchiness seemed to increase, but in this case the effect was statistically significant only for the custard-based product (MD = 13.066, $t = 2.041$, $p < 0.05$). See Figure 4. Taken together, these results do not provide consistent evidence that the fit between color and product has a connection with the cross-modal effect.

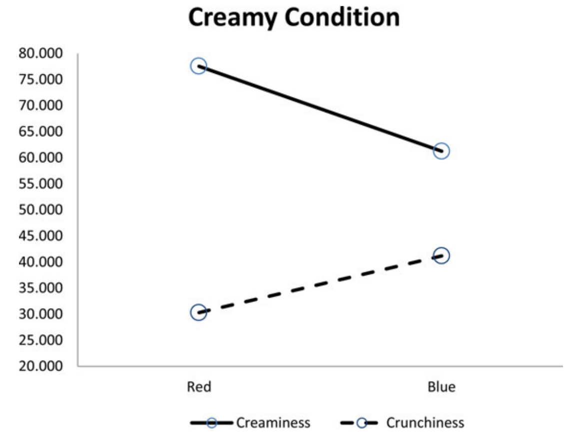

Figure 4. Cross-modal effect of color on perception of food texture (Study 2).

Discussion. Study 2 replicated the cross-modal effect observed in Studies 1a and 1b by using custard- and mayonnaise-based products. In contrast to our supposition (H2), there was no consistent evidence for the influence of a fit between color and product type in our sample. Accordingly, the results favor the belief that the cross-modal effect holds across a range of products, some of which may or may not be typically associated with the red or blue color. As such, it argues against the learned association effect, but leaves the option of embodied cognition as a viable hypothesis. Since an embodied cognition effect might be influenced by individual predispositions to the sense of touch, one way to investigate its nature is to study the cross-modal effect in relation to the existing NFT scales.

Study 3: Cross-modal Interactions and NFT

Study 3 focused on the embodied cognition implication of cross-modal perception by looking for the moderating role of NFT (H3).

Participants. Participants in the experiment were undergraduate and postgraduate students from various schools of a major university. The final sample contained data from 464 participants, 55.2% of whom were female. The mean age of the respondents was 22.1 years (SD = 3.1); ages range from 18 to 41 years. Participants were recruited through the university's research subject pool using ORSEE software and received course credit in return for their participation.

Procedure. Study 3 applied a within-subject design based on the four product combinations introduced in Studies 1a, 1b, and 2. That is, participants tried each of the four snacks (almonds with light yogurt, muesli with full-cream yogurt, chocolate with custard, and pine nuts with mayonnaise) one at a time in a random order while taking a bite of a dry cracker and drink of water before each snack. Snacks were set on standard white plastic spoons and covered with white sheets of paper to the left of the computer screen. The spoons were labeled A, B, C, or D and instructions on the computer screen (administered via the Qualtrics online survey tool - www.qualtrics.com) directed participants to try particular snack and then to answer a set of survey questions about that snack.

Experimental Manipulations: Study 3 used a mixed within-between subject design that manipulated the 2 (texture: creamy vs. crunchy) × 2 (color: red vs. blue) between participants, and product type (almonds with light yogurt, muesli with full-cream yogurt, chocolate with custard, and pine nuts with mayonnaise) within participants (i.e., every participant tried all four product types in a random order). In addition, the saturation of the color manipulations was reduced compared to Studies 1 and 2 to investigate robustness of the cross-modal effect. Participants were randomly assigned to one of the four resulting between subject groups: creamy/red (n = 118), creamy/blue (n = 115), crunchy/red (n = 116), and crunchy/blue (n = 115). The full ingredient list is provided in the Table A1. The average duration of the experiment was 45 minutes with 30-minute preparation time between the sessions.

Measures. In addition to the measures described in Studies 1 and 2, study 3 also collected information about the respondents' personal predisposition for the NFT (Peck & Childers, 2003aa), as well as measures for perceived pleasure (Sweeney & Soutar, 2001), quality (Yoo, Donthu, & Lee, 2000), and intention to purchase (Baker & Churchill, 1977) for each of the snacks.

Results. Manipulation Checks: As before, the authors examined the manipulation checks for the aspects of flavor, texture (creaminess vs. crunchiness), and color (red dye vs. blue dye) of the snacks. Table A2 summarizes the results of the multivariate GLM run on the perceived aspects of flavor. The results reveal significant differences between the four snacks in line with the ingredients used in each snack. Repeated measures GLMM run on the perceived intensity of creaminess (creamy texture condition = 64.75, crunchy texture condition = 50.84, $F(1, 1839) = 104.04$, $p < 0.001$) and crunchiness (creamy texture condition = 33.11, crunchy texture condition = 39.85, $F(1, 1839) = 26.46$, $p < 0.001$) of snacks reveals significant main effect of the texture condition on both these measures. Similarly, repeated measures GLMM run on the perceived red color (red dye condition = 53.46, blue dye condition = 7.56, $F(1, 1733) = 5178.88$, $p < 0.001$) and perceived blue color (red dye condition = 3.93, blue dye condition = 49.07, $F(1, 1566) = 5178.88$, $p < 0.001$) of snacks reveals significant main effect of the color condition based on both of these measures.

NFT Interaction: The objective of Study 3 was to test the hypothesis that NFT will moderate the cross-modal effect of texture and color on perceptions of texture. Full-factorial repeated measures random intercept GLMM using standardized variables (including dye color and food texture as factors, and NFT as covariate) replicated the interaction effect of color and texture in the case of the perceived creaminess measure ($\beta = 0.126$, $F(1, 1848) = 12.253$, $p < 0.000$). In addition, it indicated a significant interaction between the cross-modal effect (color × texture) and NFT ($\beta = -0.095$, $F(1, 1848) = 4.475$, $p < 0.05$).

Analyzing the hypothesized conditional effect at values of NFT (model 4; according to Hayes, 2012) suggested that on average, high levels of NFT boosted sensitivity to the cross-modal interaction (Effect = 0.172, $t = 2.878$, $p < 0.01$), while low levels of NFT had no statistical effect (Effect = 0.044, $t = 0.726$, $p > 0.10$). These results suggest that the effect of color on perceived texture is a cross-modal effect and that the effect is dependent on high levels of haptic sensitivity, which predicts the direction of the conditional effect in H3.

Discussion. Study 3 focused on the embodied nature of cross-modal interaction. By using all four products it replicated the cross-modal effect observed in the previous studies across the different products. Importantly, the results show a three-way interaction among color, texture, and NFT. In particular, high levels of NFT boost the cross-modal effect (color × texture) as hypothesized in H3. This result, according to current literature, appears to be the first indication of the role of haptic sensitivity and embodied cognition in relation to cross-modal perception.

Study 4: Cross-modal Interactions and Marketing Metrics

Study 4 considered the "so what?" question. That is, it looked at the role of the sensory variables in relation to standard marketing metrics such as purchase intent, product quality, and pleasure (H4).

Design. Study 4 used the marketing metrics data from Study 3 and compared a set of partial least squares (PLS) models in relation to the cross-modal effects of color and product texture.

Results. To assess the reliability and validity of the measures, individual item reliabilities were calculated,

Table 2. Measurement Statistics.

Constructs[a]	Items	Loading[b]
Pleasure (CR = 0.98, AVE = 0.89)	The product is one that I would enjoy.	0.96
	The product would make me want to crave it.	0.92
	This product would make me feel good.	0.93
	This product would give me pleasure.	0.95
	This product is one that I would feel relaxed about eating.	0.96
Purchase intent (CR = 0.96, AVE = 0.89)	Would you like to try this product?	0.95
	Would you actively seek out this product (in a store in order to purchase it)?	0.96
	Would you buy this product if you happened to see it in a store?	0.91
Quality (CR = 0.93, AVE = 0.70)	The product is of high quality.	0.81
	The product must be of very good quality.	0.79
	The likelihood that the product would be functional is very high.	0.75
	The likely quality of the product is extremely high.	0.79
	The product appears to be of very poor quality.	0.80
	The likelihood that the product is reliable is very high.	0.55

[a]Measurement model loadings for items of constructs. All items are greater than 0.50 as suggested by Hulland (1999).
[b]Average variance extracted (AVE), and composite reliability of measures (CR), which is calculated as follows: $(\sum \lambda_{yi})^2/[(\sum \lambda_{yi})^2 + \sum var(\varepsilon_i)]$, where $var(\varepsilon_i) = 1 - \lambda_{yi}$ (Fornell & Larcker, 1981).

Table 3. Construct-level Measurement Statistics and Correlation of Constructs[a].

	1	2	3	4	5	6
1. Color	–					
2. Creaminess	–0.05	–				
3. Crunchiness	–0.07	0.04	–			
4. Pleasure	–0.05	0.16	–0.03	**0.94**		
5. Purchase intent	–0.04	0.16	–0.02	0.88	**0.94**	
6. Quality	–0.00	0.15	0.02	0.67	0.66	**0.84**

[a]Diagonal entries show the square roots of average variance extracted, others represent correlation coefficients. Values in bold indicate the respective reliability.

as well as composite reliability and average variance extracted (AVE). As shown in Table 2, all factor loadings of focal constructs (i.e., pleasure, purchase intent, and quality) were greater than the minimum cutoff suggested by Hulland (1999), indicating adequate item reliabilities. In addition, support was found for convergent validity because composite reliability values of focal constructs in the model exceeded the threshold of 0.7 (Fornell & Larcker, 1981; Nunnally, 1978).

To assess discriminant validity of each construct, analysis was guided by Gaski and Nevin (1985), who stated that satisfactory discriminant validity among constructs is obtained when the correlation between two constructs is not higher than their respective reliability estimates. As shown in Table 3, results indicate that discriminant validity is evident as no individual correlations (ranged from 0.00 to 0.88) were higher than their respective reliabilities (ranged from 0.93 to 0.98).

To test mediation, the authors followed the method recommended by Preacher and Hayes (2008) and Zhao, Lynch, and Chen (2010) as outlined by Hair, Hult, Ringle, and Sarstedt (2014) and reported in Table 4. With respect to H4a, the direct relationship between color and pleasure is positive and significant in the absence of the mediator, creaminess (Model 1, $\beta = –0.05$; $t = 2.06$). When creaminess is included, color has a positive and significant effect on creaminess (Model 2, $\beta = 0.05$; $t = 2.04$). Creaminess, in turn, positively and significantly impacts pleasure (Model 2, $\beta = 0.16$; $t = 7.34$). Moreover, the direct path from color to pleasure is reduced in magnitude and becomes insignificant (Model 2, $\beta = –0.04$; $t = 1.81$). The variance accounted for (VAF) was then calculated to determine the size of the indirect effect in relation to the total effect, which is 0.25. Therefore, 25% of the total effect of color on pleasure is indirect, indicating that partial mediation via creaminess, supporting H4a. Similarly, with respect to H4b, the direct relationship between color and purchase intent is positive and significant in the absence of the mediator, creaminess (Model 1, $\beta = –0.04$; $t = 2.03$). When creaminess is included, color has a positive and significant effect on creaminess (Model 2, $\beta = 0.05$; $t = 2.04$). Creaminess, in turn, positively and significantly impacts purchase intent (Model 2, $\beta = 0.16$; $t = 7.44$). Moreover, the direct path from color to purchase intent is reduced in magnitude and becomes insignificant (Model 2, $\beta = –0.03$; $t = 1.60$). The VAF by the indirect effect is 0.36. Thus, 36% of the total effect of color on purchase intent is indirect, indicating partial mediation via creaminess, supporting H4b.

As reported above, color has no significant effect on quality (Model 1). As a result, it was not possible to test the mediation effect of creaminess on the relationship between color and quality, thus H4c is not supported. With respect to crunchiness, color has significant effect on crunchiness (Model 2, $\beta = 0.07$; $t = 2.95$), which however has no significant effect on pleasure (Model 2, $\beta = –0.04$; $t = 1.71$), purchase intent (Model 2, $\beta = 0.03$; $t = 1.19$), and quality (Model 2, $\beta = –0.02$; $t = 0.62$). Thus, crunchiness is not a mediator of the relationship between color and pleasure (4d), purchase intent (4e), and quality (4f).

Discussion. Study 4 examined the extent to which the sensory variables (e.g., perceived creaminess and

Table 4. **Test of Hypothesized Relationships: Beta Coefficients and t-Values[a].**

	Endogenous Variables							
	Model 1					Model 2		
Exogenous Variables	Pleasure	Purchase Intent	Quality	Creaminess	Crunchiness	Pleasure	Purchase Intent	Quality
Color	−0.05* (2.06)	−0.04* (2.03)	−0.04 (0.88)	0.05* (2.04)	−0.07* (2.95)	−0.04 (1.81)	−0.03 (1.60)	0.01 (0.21)
Creaminess	–	–	–	–	–	0.16* (7.34)	0.16* (7.44)	0.15* (6.10)
Crunchiness	–	–	–	–	–	−0.04 (1.71)	−0.03 (1.19)	0.02 (0.62)
Control (texture)	–	–	–	−0.24* (10.57)	0.11 (4.84)	–	–	–

[a] t-Values reported in parentheses.
* $p < 0.01$.

perceived crunchiness) may account for the effects of color on standard marketing metrics such as pleasure, purchase intent, and quality. In line with the supposition, it is not color per se but rather the active role of creaminess that influences customers' perception of pleasure and purchase intent. Specifically, the findings offer new insights that color's potential for influencing pleasure and purchase intent can be realized, in part, through perceived creaminess texture. Interestingly, the results showed no direct effect between color and quality; as such creaminess is not a concern. In contrast to creaminess, the findings show that crunchiness has no effect on pleasure, purchase intent, and quality. The inactive role of crunchiness, in contrast to creaminess as a mediator of color-metrics linkages strengthens prior research that found crunchiness and creaminess may have an inverse relationship to each other.

GENERAL DISCUSSION

The primary objective of this research was to explore the cross-modal interactions between vision and touch. Across four studies, the findings show that the human sense of touch perceives texture through a cross-modal interaction involving color and actual texture. Studies 1a and 1b showed that red and blue colors positively influence perceptions of creaminess and crunchiness, respectively. However, while the use of red and blue colors might be appropriate for some food types (i.e., ice cream or chocolate), for many it would seem highly inappropriate. For this reason, Study 2 was undertaken to account for any potential issues surrounding color–product fit. The results showed the underlying cross-modal interactions between color and texture hold regardless of product type or its fit with the color.

The results of the first two studies build on the model put forward by Labrecque, Patrick, and Milne (2013) and show that synesthesia-like cross-modal interactions between color and texture are embodied and automatic. Moreover, they are independent of any learned, referential meaning. At first glance, the findings show a distinct directional effect between the colors (red/blue) and perceived textures (creaminess/crunchiness), such that red tends to accentuate creaminess, while blue will accentuate crunchiness. On closer inspection, though, the results indicate a possible bias toward the hedonic role of creaminess. In Study 1a, this meant that for the creamy product, red color suppressed the perceived crunchiness. By contrast, for the crunchy product, the red color amplified the perceived creaminess. However, in Study 1b, the actual texture of the product was adjusted so that the creamy product was made even creamier. Once the dominant texture became creaminess, the perceived creaminess became the focal point for any color–texture interaction.

Since the literature suggested at least two plausible (though not mutually exclusive) mechanisms behind the cross-modal effect of color and texture, the authors chose to investigate both. The type of product affected cross-modal interaction in Studies 1a and 1b; it seemed reasonable it might do so in Study 2 that considered product fit. Because some products like custard may be associated with red or blue color more often than mayonnaise, Study 2 implicitly tested the role of acquired knowledge in relation to the cross-modal effect. The results, however, found no consistent effect for product fit; there was no interaction or mediation effect. The means analysis suggested custard and mayonnaise responded to color changes but the pattern was not consistent to allow reliable rejection of the null to H2.

While the initial studies identified cross-modal interactions between vision and the sense of touch, Study 3 explored the role a person's haptic predisposition, or NFT, plays in such interactions. Conceptually, it was proposed that a person's NFT would moderate the cross-modal color–texture interaction. The results show that, in line with current literature, those people with high NFT tend to be more sensitive to haptic stimuli. This increased sensitivity manifested itself in a heightened awareness and response to the cross-modal interactions between color and texture. Because of this, the findings extend current research and indicate the influence of a person's predisposition to physical interaction is not necessarily limited to cutaneous or kinesthetic experiences. Instead, a person's NFT may play a role in cross-modal awareness and have the capacity to shape perception across other sensory modalities. This dovetails nicely with the findings from Studies 1 and 2, in that it reinforces the embodied aspects of cross-modal interactions involving color.

In Study 4, the results were analyzed using PLS regression to better understand the influence of the cross-modal (color–texture) effect on marketing metrics. On its own, color is found to have a significant influence on expected pleasure and purchase intent. However, when creaminess is included in the model, texture mediates the relationship so that the paths for color–pleasure and color–purchase intent become insignificant. Effectively, this indicates that the sensory-level cross-modal interactions in the first three studies are driving higher-order constructs. So, in the first instance, actual texture and color interact to shape perceived texture. From this point, the perceived texture, specifically creaminess, takes command of the process and, ultimately, determines expected pleasure and purchase intent. While this offers a neat explanation of cross-modal interactions through the consumer decision process, it raises a number of questions for future research.

Since multiple sensory inputs are necessary to form the typical marketing evaluations such as pleasure, quality, or intention to purchase, investigation of the cross-modal effects in different sensory modalities suggests new ways in which marketing stimuli may be related with consumer behavior. In this study, the interaction between color and actual texture on perceptions of texture was demonstrated. However, in many retail settings (especially where food products are involved) texture is inferred from cues other than actual texture; such as shape and size of labels or packaging, language, and/or sounds used during marketing communications. At this stage, it is not clear if cross-modal interactions persist in settings where direct sensory information is not available, and must be inferred from secondary cues. That is, how can advertisers use cross-modal effects in communicating texture with customers? A future study of when selective sensory information can be removed or included will help researchers better understand the nature of cross-modal interactions. Additionally, this research found the effects using the color and texture of the product as variables. However, color perception in particular is sensitive to the color of the background context (Jameson & Hurvich, 1972). In our study, the context was primarily black and white: white laboratory desk, white plastic spoons, white sheets of paper to cover the spoons, and black computer peripherals. Most real-world settings are not so clinical. In fact, vibrant color is used extensively as background in retail settings (e.g., grocery and department stores), and consumption settings (e.g., restaurants; Bellizzi & Hite, 1992). Currently, researchers do not fully understand the implications of background color on the cross-modal effects of perceived texture. For example, how can cross-modal effects be enhanced or suppressed by the use of background color? Further exploration of this concept would serve to better explicate the effects of cross-modal interactions. Also, in the current experiments participants ate the product, which means they first saw the lunch snack and then realized its texture in the mouth (see Labrecque, Patrick, & Milne, 2013, p. 199—RQ12). The cross-modal effect postulated suggests a blending of the two sensory inputs. However, there is a clear sequence in the order in which the sensations were experienced. Blending of the sensory inputs requires additional cognitive processing based on memory and/or expectation formation to extend the influence of color beyond the immediate sensation. As such, the role of semantic processing in formation of expectations deserves additional study in the context of cross-modal associations. Similarly, the role of memory in relation to cross-modal information processing is not fully understood in the literature (Gallace & Spence, 2009). However, from the marketing perspective this is highly relevant. Consumers rarely approach a purchase or consumption situation without a set of existing priors. These priors are often based on advertising, word of mouth, or previous experience. Priors that help or hinder cross-modal processing remain an important research question in the area of cross-modal sensory integration.

The results have several managerial implications. They provide evidence that perception of food texture changes with the change in color hue. In addition, the consumer's haptic sensitivity affects the processing of such cross-modal interactions. The decision for selecting the color of a product, therefore, should consider both the consumer's underlying sensory integration processes, and the market segment for which the product is intended. In particular, it was demonstrated that perceived texture mediates the effects of color on the extent to which consumers like the product, and their intentions to purchase the product. Ultimately, the effect of cross-modal information processing on marketing metrics is an underexplored domain that provides a fascinating link among marketing stimuli, consumer behavior, and marketing outcomes.

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Appendix

Table A1. Ingredients and Formulations.

	Studies 1–2				Studies 3–4			
	Creamy Red	Crunchy Red	Creamy Blue	Crunchy Blue	Creamy Red	Crunchy Red	Creamy Blue	Crunchy Blue
Product A								
Yogurt (g)	1000	1000	1000	1000	1000	1000	1000	1000
Muesli (g)	100	400	100	400	100	400	100	400
Red (ml)	19	19	19	1.9	1.9	1.9	1.9	1.9
Blue (ml)								
Product B								
Custard (g)	1000	1000	1000	1000	1000	1000	1000	1000
White chocolate (g)	200	400	200	400	200	400	200	400
Red (ml)	19	19	19	19	1.9	1.9	1.9	1.9
Blue (ml)								
Product C								
Mayonnaise(g)	1000	1000	1000	1000	1000	1000	1000	1000
Pine nuts (g)	100	300	100	300	100	300	100	300
Red (ml)	19	19	19	19	1.9	1.9	1.9	1.9
Blue (ml)								
Product D								
Sour cream(g)	1000		1000		1000		1000	
Light yogurt (g)		1000		1000		1000		1000
Almond flakes (g)	300	300	300	300	300	300	300	300
Red (ml)	19	19	19	1.9	1.9	1.9		
Blue (ml)							1.9	1.9

Table A2. Multivariate GLM on Aspects of Flavor for Each of the Snacks Used in the Experiment.

		Custard and Chocolate			Mayonnaise and Pine Nuts			Full-cream Yogurt and Muesli			Light Yogurt and Muesli		
	Study	1	2	3	1	2	3	1b	2	3	1a	2	3
Taste	Salty		7.20 (2.11)	6.24 (1.11)		52.42 (2.17)	56.78 (1.11)	16.89 (1.46)		23.78 (1.11)	18.29 (2.06)		24.28 (1.11)
	Sweet		83.14 (1.97)	85.66 (0.94)		18.37 (2.03)	12.28 (0.94)	30.27 (1.64)		16.17 (0.94)	21.19 (1.97)		15.08 (0.94)
	Bitter		2.57 (1.50)	2.99 (1.06)		10.68 (1.55)	15.18 (1.06)	15.21 (1.52)		21.47 (1.06)	10.08 (1.62)		17.10 (1.06)
	Sour		3.65 (2.28)	4.55 (1.31)		35.47 (2.35)	42.53 (1.31)	50.66 (2.12)		62.35 (1.31)	63.86 (2.59)		59.19 (1.31)
Smell	Milky		59.58 (2.37)	59.07 (1.26)		23.72 (2.44)	22.09 (1.26)	37.87 (1.91)		28.79 (1.26)	37.01 (2.62)		35.62 (1.26)
	Vanilla		61.41 (2.14)	61.51 (1.05)		10.32 (2.21)	10.56 (1.05)	21.03 (1.56)		16.12 (1.05)	17.93 (2.06)		15.43 (1.05)
	Egg		18.06 (2.53)	19.21 (1.10)		32.40 (2.60)	29.84 (1.10)	13.26 (1.25)		14.39 (1.10)	12.22 (1.59)		17.67 (1.10)
	Sour cream		9.28 (2.42)	7.84 (1.40)		56.42 (2.40)	45.13 (1.40)	52.46 (2.15)		58.38 (1.40)	63.92 (2.72)		63.24 (1.40)
	Nutty		14.75 (2.46)	17.28 (1.41)		46.04 (2.53)	49.76 (1.41)	44.76 (2.04)		42.25 (1.41)	39.88 (2.93)		54.27 (1.41)
	Chocolate		49.23 (2.42)	46.81 (0.93)		2.56 (2.50)	3.12 (0.93)	4.92 (0.73)		3.26 (0.93)	2.46 (0.42)		3.33 (0.93)
Texture	Hard		23.91 (2.24)	15.71 (1.14)		15.96 (2.30)	19.38 (1.14)	14.97 (1.51)		17.81 (1.14)	30.94 (2.63)		35.39 (1.14)
	Soft		65.02 (2.84)	61.15 (1.40)		66.03 (2.92)	53.66 (1.40)	66.83 (2.00)		57.63 (1.40)	50.43 (3.21)		45.11 (1.40)
	Oily		23.53 (2.82)	24.93 (1.32)		51.09 (2.91)	61.17 (1.32)	19.19 (1.67)		25.79 (1.32)	18.09 (1.94)		31.46 (1.32)
	Watery		35.72 (2.69)	44.87 (1.33)		23.44 (2.77)	25.74 (1.33)	25.78 (1.80)		26.04 (1.33)	31.31 (2.44)		23.26 (1.33)
	Gummy		23.34 (2.63)	23.73 (1.37)		22.56 (2.71)	26.01 (1.37)	37.69 (1.90)		34.69 (1.37)	21.49 (2.56)		25.49 (1.37)

Note: Results show the mean estimate, and standard error in brackets.