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RESEARCH ARTICLE

Examining consumers' sensory experiences with color: A consumer neuroscience approach

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Abstract

This research advances neuroscience as a tool with which to study consumers' visual mental imagery. Applying these methods, we suggest that the presence or absence of color is a critical dimension along which consumers' visualizations can vary, and explore when and why color of visual mental imagery becomes more prominent. Using functional magnetic resonance imaging (fMRI), we find neural evidence for distinguishing black-and-white (BW) versus color visualization, and that visual mental imagery becomes increasingly monochrome (vs. colorful) when consumers imagine distant (vs. near) future events. Our neural evidence further suggests construal level as the underlying mechanism of this effect, showing common regions of activation for imagining distant future events, engaging in high-level construal, and forming BW mental imagery. We discuss the implication of these findings and the benefits of fMRI techniques for marketing in general.

KEYWORDS

color, construal-level theory, mental imagery, neuroscience, sensory experience

Encouraging visualization (i.e., visual mental imagery) is a highly influential marketing technique. Compared to simply viewing printed images in media, generating visual mental imagery leads consumers to more actively engage with the advertisements (Lorayne & Lucas, 1974; Lutz & Lutz, 1978). Consumer research has shown that the use of visual mental imagery while evaluating a product has positive impacts on attitudes and purchase intentions (Gregory, Cialdini, & Carpenter, 1982; McGill & Anand, 1989; Phillips, Olson, & Baumgartner, 1995). Such visualizations create stronger, more readily available links in memory which in turn enhances consumers' attitudes at the time of the judgment (Bone & Ellen, 1992; Carroll, 1978). Many marketers thus design their advertisements to encourage consumers to visualize their experience with the advertised products.

One particularly important dimension along which visualizations can vary is their color—the presence or absence of color in visualization. Consumers have an ability to visualize products or scenes both in color and monochrome (Wantz, Borst, Mast, & Lobmaier, 2015). Color may not be a central component of visual mental imagery all the time, but it becomes highly relevant under certain contexts (e.g., will this green sofa match the color of the living room? Wantz et al., 2015). Current marketing practice, however, tends to treat color as a default mode of visual mental imagery and dismiss the important differences between color versus black-and-white (BW) visualization. That marketers encourage consumers to visualize as vividly and colorfully as possible without considering contexts under which BW becomes relevant and effective in delivering marketing messages may be problematic. While previous research

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has extensively documented how and when direct exposure to color versus monochrome stimuli (e.g., products or advertisements) influences attention (Grønhaug, Kvitastein, & Grønmo, 1991; Hornik, 1980; Lohse, 1997), memory (Gardner & Cohen, 1964; Homa & Viera, 1988; Suzuki & Takahashi, 1997; Vandermeer, 1954; Wichmann, Sharpe, & Gegenfurtner, 2002), mental representation (Lee, Deng, Unnava, & Fujita, 2014), judgments (Bohle & Garcia, 1986; Schindler, 1986), and attitudes (Fernandez & Rosen, 2000; Meyers-Levy & Peracchio, 1995; Pallak, 1983), research has yet to document the antecedents and consequences of visualizing in color versus BW. In the present research, we propose that the presence or absence of color is a critical dimension along which visualizations can vary and highlight the different role and function of color versus BW mental imagery.

A central challenge for visual mental imagery research is that it can be difficult to directly tap into participants' visualizations. For example, visualization is generally assessed through self-report (e.g., "how vivid was your imagery?," "what did you see?," etc.). However, people may lack the introspective ability to report accurately what they experience in their minds' eye (Nisbett & Wilson, 1977)—in other words, what participants actually visualize may be divergent from what they report. This issue is particularly acute for reporting the relative color content of visualizations, as participants may rely on semantic knowledge about the objects rather than the actual color they generated in visualization (Wantz et al., 2015). Together, this raises the need for better research methods for examining visual mental imagery, particularly as it relates to the relative presence of color.

We propose that functional magnetic resonance imaging (fMRI) may provide a complementary tool to aid marketers in assessing differences in visualizations (Ariely & Berns, 2010; Plassmann, Venkatraman, Huettel, & Yoon, 2015). By investigating changes in neural activity of the brain, researchers gain an additional tool with which to understand the sensory images that people generate, as well as to explore the mechanisms underlying those visualizations. Although current methods are not yet sufficient for complete reconstruction of the specific images that consumers generate (Haynes & Rees, 2006; Huth et al., 2016; Naselaris, Olman, Stansbury, Ugurbil, & Gallant, 2015; Nishimoto et al., 2011), researchers can use neuroimaging to examine the commonalities in visual representation and their underlying processes when consumers engage in various imagery tasks. For example, research has shown that positive sensory (i.e., pleasant tastes, smells, and textures), social, and monetary rewards all activate similar neural structures—suggesting that all stimuli are commonly coded as a function of their reward value regardless of modality (Gottfried, O'Doherty, & Dolan, 2003; Izuma, Saito, & Sadato, 2008; Lin, Adolphs, & Rangel, 2012).

In the current paper, we adopt a consumer neuroscience approach to investigate systematic differences in visualization, and make three key contributions. First and foremost, we critically test the argument that color versus BW mental imagery is a critical dimension of consumers' visual mental imagery, and that they might be neurally dissociated. Such findings would add to both the marketing and neuroscience literatures, which have tended largely ignored the presence or absence of color as a variable in imagery (e.g., Chang, Lewis, & Pearson, 2013). Moreover, such findings may also serve as the conceptual ground-work with which to develop behavioral marketing predictions from the different brain regions involved in different forms of visualization.

To substantiate the importance of distinguishing color versus BW imagery, we draw on construal-level theory (CLT). Specifically, drawing from previous work that consumers visualize the distant (vs. near) future in monochrome (vs. color; Lee, Fujita, Deng, & Unnava, 2017), we predicted visualizing in BW versus color would produce neurologically distinct patterns of activation, corresponding to different functions they are hypothesized to address. In addition to documenting neurological dissociation, the present investigation offers a stronger test of past work—specifically, that generating BW (vs. color) imagery, thinking of distant (vs. near) future events, and engaging in high-level (vs. low-level) construal will activate overlapping neural regions. Critically, we highlight how consumer neuroscience methods afford researchers greater insight than traditional behavioral methods into the questions of what people visualize (i.e., is the content monochrome vs. color), when they visualize such content (e.g., temporal proximity vs. distance), and why (e.g., because of changes in construal level).

Finally, although our focus is primarily on visualization, an outstanding question is identifying the similarities and differences between visualizing versus viewing images in color versus BW. Though our theoretical model does not make predictions surrounding the differences between visualizing versus viewing, it is possible that the more active role consumers take in visualizing (vs. viewing) images will lead to relatively stronger results in the brain. On the other hand, past work in neuroscience often finds stronger effects for viewing images compared to visualizing them (O'Craven & Kanwisher, 2000). Our neuroscience setup allows us to test these competing hypotheses by examining the relative activation of the brain in response to visualizing and viewing color versus BW. In what follows, we outline why temporal distance impacts the color in visualization, what role construal level plays, and how fMRI data can complement previous behavioral research.

1 | COLOR VERSUS BW MENTAL IMAGERY

Mental imagery is defined as a sensory experience without actual sensory inputs (Barsalou, 2008; Krishna & Schwarz, 2014). Mental imagery can arise when people recall the events or objects that they perceived in the past or can be actively constructed by combining and modifying their perceived experiences stored in their memory (Kosslyn, Ganis, & Thompson, 2001). Although mental imagery can simulate visual, auditory, olfactory, gustatory, and haptic experiences, we focus specifically on visual mental imagery in this research. Visual imagery is grounded in visual perception. Although some research suggests that visual imagery and visual perception are independent, experimental and neuroimaging research have provided abundant evidence that they share the same representational systems (for a review, see Kosslyn, Thompson, & Ganis, 2006).

One question that arises in this discussion is whether visual mental imagery includes color or not. The human eye is advanced in its perception of color. With four types of light receptors (among them are three types of cones, each of which responds to a different range of color, i.e., red, green, and blue), the human eye can perceive the entire rainbow spectrum (Gegenfurtner, 2003; Kaplan, Lee, & Shapley, 1990; Stockman & Sharpe, 2000). Given that our visual perception heavily relies on color, should we assume that our visual mental imagery also always includes color? Although recent research has started investigating the relationship between color perception and color imagery (Bramão, Faísca, Forkstam, Reis, & Petersson, 2010; Hsu, Frankland, & Thompson-Schill, 2012), whether color is voluntarily represented in visual mental imagery is largely unknown (Chang et al., 2013).

In this research, we argue that just as people can visually experience both BW and color stimuli, they can generate both BW and color imagery in their minds' eyes. More important, using fMRI techniques, we test to what extent BW versus color imagery can be neurally distinguished. In what follows, we discuss the theoretical background regarding when and why people visualize in BW versus color, and what mechanism underlies this effect.

2 | CONSTRUAL-LEVEL THEORY

CLT attempts to explain how people think about events that differ in psychological distance—the degree to which events are removed from the direct experience of "here-and-now." CLT suggests that time is one of the primary dimensions of psychological distance. Events that occur next year, for example, are more psychologically distant than events that occur tomorrow. One challenge people encounter when construing temporally distant events is that details about these events are typically unknown and unreliable. In response, CLT suggests that people engage in high-level construal—a representational process that highlight the abstract, invariant, and essential features of events. By focusing on essential invariants, people are able to orient to and think about distant events despite the absence of details. As events become proximal and details becomes more available and reliable, people engage in low-level construal—a representational process that spotlights incidental and concrete specifics. This allows people to create idiosyncratic event representations tailored to the unique features of events. This distance-construal link, moreover, is overlearned: people use high-level construal for distant events and low-level construal for near events even if information is held constant (Bar-Anan, Liberman, & Trope, 2006).

Construal level can also be directly manipulated independently of distance—inducing differences in construal level in one task can lead to a carry-over effect in subsequent unrelated tasks (Freitas, Gollwitzer, & Trope, 2004; Fujita & Trope, 2014). For example, having participants think about why versus how they engage in an action (highlighting abstract ends vs. concrete means) leads them to construe subsequent actions in higher versus lower level terms (e.g., Freitas et al., 2004). This allows researchers to manipulate construal level directly, with important implications for understanding the cognitive mechanisms proposed by CLT.

3 | FUTURE-DIRECTED IMAGERY

Drawing from CLT, Lee et al. (2017) proposed that imagining distant (vs. near) future results in visualizations that are more monochrome (i.e., less colorful). This hypothesis is derived from the insight that whereas shape is (generally) an essential and invariant "high-level" visual feature, color is an incidental and variable "low-level" visual feature. Two arguments support this assertion. First, the perception of shape is less context-dependent than color. The perception of color can vary depending on the brightness of the environment or viewing angle, whereas the perception of shape tends to be stable regardless of situational variance (Arnheim, 1974). Second, shape compared to color can effectively convey the essential nature and meaning of objects (Brockmann, 1991; Dooley & Harkins, 1970; Rossiter, 1982). Modifying the shape of an object (sedan vs. bus) can alter its meaning and nature; changing the color of an object (blue vs. red sedan), by contrast, generally does not (Biederman, 1987; Biederman & Ju, 1988; Lowe, 1984; Mapelli & Behrmann, 1997). Although sometimes color (e.g., green or yellow) can be critical information in judgment (e.g., whether a banana is edible or not), in general shape relative to color plays more important role in conveying the essential nature of objects (Brockmann, 1991; Dooley & Harkins, 1970; Rossiter, 1982).

Given that shape (vs. color) is a high-level (vs. low-level) visual feature, Lee et al. (2017) proposed that temporal distance influences the extent to which people use these two types of information in constructing their visual representations of future events. People should focus more on shape (relative to color) to visualize temporally distant future events, which should result in more monochrome mental images. As events become closer in time, people should increasingly incorporate color information in addition to primary shape information, which in turn makes mental images more colorful.

Note the functional basis for visualizing distant (vs. near) future events in monochrome (vs. color). CLT suggests that, because details of the distant future events tend to be uncertain and changeable, it is more efficient to focus on invariant and essential high-level (vs. variable and incidental low-level) features to represent the distant future. People maximize the utility of the available and reliable information at the given time to imagine the future. Rather than incorrectly making assumptions about what colors may be present, it is more efficient to visualize the distant (vs. near) future based on more stable and reliable shape information.

In a series of experiments, Lee et al. (2017) provided initial empirical evidence in support of these predictions. When asked to imagine distant versus near-future events, participants reported using more monochrome versus color images, respectively. However, methodological criticisms can be leveled at this past work. For example, these studies largely relied on self-report, leaving open the possibility that participants' reports did not accurately reflect what they actually imagined. To address this possibility, Lee et al. (2017) attempted to assess visualization in some of their studies using more indirect methods. For instance, some studies presented photos of the same scene that differed only in their level of color saturation and asked participants to choose which most closely corresponded to the event that they had imagined. Although participants tended to select the less saturated photo after imagining a distant versus near-future event, it is always possible that none of the options presented captured their actual visualizations. Participants may have simply selected the image that was least inconsistent with respect to the detailed colors that they had imagined—that is, the more monochromatic images. Questions thus remain about what participants actually experienced in these studies—what they saw in the minds' eye—as they imagined distant versus near-future events.

4 | THE CURRENT RESEARCH AND HYPOTHESES

To document that the presence or absence of color may be an important dimension along which visualizations vary, as well as to provide stronger evidence for the correspondence between BW, distance, and high-level construal (and color, proximity, and low-level construal), we employ fMRI. As it does not rely on self-report or forced-choice assessment, fMRI is particularly well-suited for studying visualizations. Figure 1 summarizes our hypotheses.

We first test whether or not forming BW versus color imagery activates differential neural regions (H1). In contrast to previous research (Lee et al., 2017), we directly manipulate color versus BW mental imagery and measure the neural response to each. This method allows us to examine to what extent BW versus color visualization activate unique brain regions. To the extent that they activate distinct regions, this might suggest that BW versus color imagery are distinct—an insight with important implications for both researchers and marketers.

Hypothesis 1. *Engaging in BW versus color imagery activates differential neural regions.*

Next, we investigate whether imagining distant (vs. near) future events activates similar neural regions as those involved in forming BW (vs. color) imagery (H2). Drawing from the findings from Lee et al. (2017), we examine temporal distance as one of the antecedents that induces BW versus color visualization. As fMRI methodology bypasses the limitations of self-report measures as mentioned above, the neurological evidence can supplement the previous behavioral finding and suggest temporal distance as one of the important contexts in which the color of visualization is relevant in delivering marketing messages.

Hypothesis 2. *Imagining distant (vs. near) future events activates similar neural regions as those involved in forming BW (vs. color) imagery.*

Third, we investigate whether tasks involving high-level construal (vs. low-level construal) activate similar neural regions as those involved in forming BW (vs. color) imagery (H3). Lee et al. (2017) suggest construal level as a common underlying mechanism between temporal distance and color of imagery. Although an association between chromaticity and construal was tested in one study, it still suffers from methodological limitations associated with self-report. It is also possible that BW versus color imagery and high-level versus low-level construal, respectively, are associated yet distinct cognitive processes. By contrast, we might suggest there is a deeper, more fundamental relationship—specifically, that because they meet similar functional demands, they require similar cognitive and neural operations. If they are indeed fundamentally related, we should observe overlapping neural regions involved in BW (vs. color) imagery and high-level (vs. low-level) construal. This investigation can provide a significant contribution to CLT by providing the first neurological evidence on what cognitive processes, such as high-level versus low-level construal, look like in our mind's eyes.

Hypothesis 3. *Engaging in high-level construal (vs. low-level construal) activates similar neural regions as those involved in forming BW (vs. color) imagery.*

Finally, we test whether imagining distant (vs. near) future events, forming BW (vs. color) mental imagery, and engaging in high-level (vs. low-level) construal all activate similar neural regions (H4)—a three-way neural overlap. A neuroscience approach allows us to test all components of the theory simultaneously, thus providing (a) the first evidence that all three correspond simultaneously (in contrast to past research, which has only made pairwise comparisons), and (b) constitutes a very strict test of construal-color correspondence.

Hypothesis 4. *Imagining distant (vs. near) future events, forming BW (vs. color) mental imagery, and engaging in high-level (vs. low-level) construal all activate similar neural regions.*

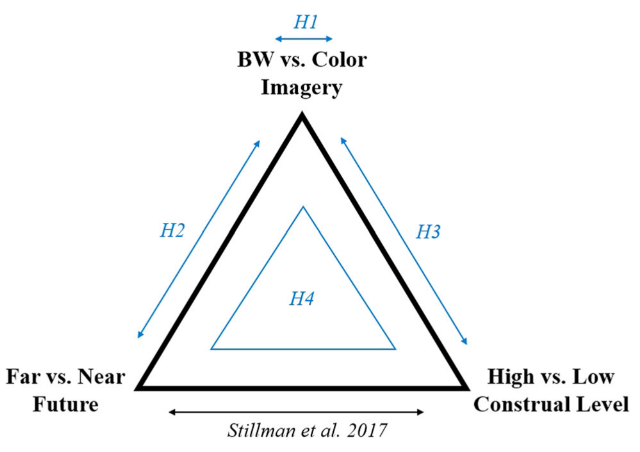

FIGURE 1 Summary of hypotheses [Color figure can be viewed at wileyonlinelibrary.com]

In addition to these hypotheses, our methodology allowed us to investigate whether visualizations of color versus BW would produce similar or dissimilar patterns of neural activations to simply viewing images in color versus BW. Current marketing practices heavily relies on passive image viewing rather than visualization. By investigating the fundamental differences in visualizing versus viewing, we had the opportunity to provide novel insights into visual marketing.

To test these hypotheses, we analyzed data that was collected (but not yet analyzed and published) from the same participants described extensively by Stillman et al. (2017). This prior work found a two-way neural overlap: overlapping neural regions involved in visualizing the distant future and high-level construal, as well as overlapping neural regions involved in visualizing the near future and low-level construal. Here we extend those findings by examining yet unanalyzed and unpublished data obtained during the same experimental session during which participants engaged in two inductions of color versus BW imagery.

5 | METHODS

5.1 | Participants

Thirty right-handed participants (21 female, ages 18–30) with no abnormal neurological history provided informed consent and were paid $25 for participating in the experiment.

6 | MANIPULATIONS OF COLOR, CONSTRUAL, AND DISTANCE

Participants completed several tasks while undergoing fMRI, each designed to elicit our processes of interest. Each task lasted the entire functional run (~6 min), and each had the same form: participants completed trials of both conditions (BW vs. color; high-level vs. low-level construal; distant vs. near future) in a block design such that participants completed several of the same type of trial and then alternated to complete several trials of the opposing condition. The different tasks were completed in random order, with the exception that the two color of imagery tasks were completed sequentially (we randomly determined which task came first).

6.1 | Color of imagery

To test the possibility that active visualization versus passive viewing may involve different neural substrates, we used two tasks—an image generation task and a passive image-viewing task—to manipulate whether participants were processing in BW versus color. In the first, we gave participants different objects and actions (e.g., “bird,” “a man doing laundry,” see the Appendix for a complete list) and asked them to imagine that object in either BW or color. As the active generation of BW versus color images may be more unusual and, therefore, more difficult for participants, participants completed several practice trials, and were given a strategy with which to generate the BW images (“pretend you are seeing it in a BW movie”). Each of the eight blocks consisted of seven trials, each lasting 4 s, with 5 s of fixation in between blocks. Participants were instructed to construct the image in their minds' eye for the entire duration of the trial.

In the second task, participants passively viewed blocks of BW images and blocks of color images (30 images per block, each image lasting 1 s, 10 blocks total). Participants would see 30 color images, followed by 30 BW images, followed by 30 color images, followed by 30 BW images, and so on for 5 min total (whether the starting block was color or BW was counterbalanced between subjects). Images were drawn from a set of 300, and color of the image was manipulated between subjects (i.e., different participants saw different images as either color or BW). We note that past research using a similar task failed to find neural differences between images that varied in color (Brouwer & Heeger, 2009), but we nevertheless opted to implement this task given its face-valid manipulation of color imagery, and its relevance to marketers.

6.2 | Construal level

For our direct manipulation of construal, we used the why-how localizer developed by Spunt and Adolphs (2014; see also Freitas et al., 2004). Participants responded yes/no to image/question pairs that required consideration of either the superordinate goal that the action in the image served (e.g., “Is this person protecting themselves;” high-level construal) or subordinate means used to accomplish that action (e.g., “Is this person using both hands;” low-level construal). The task consisted of 16 blocks of eight images each. At the beginning of each block, participants were presented with a question for 2 s, and answered either “yes” or “no” (via a button box) for each of the eight images. Each image was displayed for 1.75 s, followed by a reminder of the question prompt for 0.35 s. Of the eight images, “yes” was the correct answer for 5 and “no” was the correct answer for 3. Each block was followed by 2 s of fixation. Each image was repeated twice so that the same image would be present for both high- and low-level trials. We selected one randomized presentation order for all participants, which Spunt and Adolphs (2014) optimized to maximize efficiency.

6.3 | Temporal imagery

To manipulate distant- versus near-future imagery, participants imagined engaging in an activity (e.g., “going to a party,” see the Appendix for a complete list) either 5 years from now versus tomorrow, respectively. As we were concerned that imagining one's life 5 years from now may be more difficult than imagining one's life tomorrow, before entering the scanner and again before the start of the run, we asked participants to take a minute or two to consider their life 5 years from now. Participants then completed alternating blocks in which they imagined distant and near-future actions. Each of the six blocks consisted of five trials, each lasting 8 s. Following each block was 5 s of fixation followed by 5 s of a prompt that read "please imagine the next events occurring FIVE YEARS FROM NOW [TOMORROW]". Details of fMRI acquisition, preprocessing, and analyses are given in the Methodological Details Appendix.

We note that the manipulations and data of the construal level and temporal distance tasks have been previously reported in Stillman et al. (2017)[1] That paper reported the results based on these two tasks, showing that visualizing the distant (vs. near) future recruited overlapping regions as high- (vs. low-) level construal, and thus providing the first neurological evidence for the distance-construal link. The present paper thus includes a reanalysis of these previously published data in addition to color of imagery data (which were not previously reported) to provide the first neurological evidence for distinguishing BW versus color imagery, and their relationships with temporal distance versus proximity and high-level versus low-level construal, respectively.

7 | fMRI ACQUISITION, PREPROCESSING, AND ANALYSIS

7.1 | fMRI parameters

We conducted the neuroimaging using a Siemens 3T Trio scanner. Functional images were acquired using a single-shot gradient echo-planar pulse sequence (echo time = 28 ms, repetition time = 2.1 s, in-plane resolution = 2.5 × 2.5 × 3.2 mm, field of view = 250 mm).

7.2 | fMRI preprocessing

We prepared the data using FSL (FMRIB Software Library, www.fmrib.ox.ac.uk/fsl). Data preprocessing were carried out using FEAT (FMRI Expert Analysis Tool) Version 6.00. The following pre-processing transformations were applied: motion correction using MCFLIRT (Jenkinson & Smith, 2001), nonbrain removal using the brain extraction tool (Smith, 2002), spatial smoothing using a Gaussian kernel of FWHM 6 mm, grand-mean intensity normalisation of the entire 4D dataset by a single multiplicative factor, and high-pass temporal filtering (Gaussian-weighted least-squares straight line fitting, with sigma = 45 s). Following this, nonlinear registration to high-resolution structural and Montreal-Neurological Institute standard space images was performed using FNIRT (Jenkinson & Smith, 2001; Jenkinson, Bannister, Brady, & Smith, 2002).

[1]In addition to why-how manipulation, participants completed another construal-level induction—a modified category exemplars task (Fujita, Trope, Liberman, & Levin-Sagi, 2006). However, given some issues with the adaptation of this task to the fMRI context, we do not discuss it further here. Details and extensive discussion can be found in Stillman et al. (2017) and Gilead et al. (2014).

7.3 | General linear model

To identify regions active in response to our conditions of interest (near/distant future, color/BW, low-level construal/high-level construal), for each task we modeled BOLD activity from six motion parameters and two regressors corresponding to each condition (obtained by convolving block timings with a double-gamma hemodynamic response function). We took contrasts of the resulting activation maps, yielding maps corresponding to one of our conditions of interest (e.g., why > how, color > BW). We then applied a white matter/csf mask to these contrast maps, then applied a threshold at $p < .001$. For cluster correction, we ran 3dFWHMx on the resulting residuals to estimate the smoothness of our data (using the autocorrelation function option to protect against overly liberal thresholds, Cox, Chen, Glen, Reynolds, & Taylor, 2017), which we then input to 3dClustSim, which yielded a cluster correction such that to survive correction there had to be at least 60 contiguous voxels significant at $p < .001$, resulting in a threshold of $p < .05$ corrected. For the color tasks, initial results suggested that no voxels of either activation map survived the initial threshold of $p < .001$. For these maps, then, we instead used a whole-brain threshold of $p < .05$ uncorrected, before applying our cluster correction (e.g., Gilead, Liberman, & Maril, 2014). To compare activation of these contrast maps across task, we performed a number of conjunction analyses, which take the intersection of two contrast maps (contrast A ∩ contrast B), leaving only the voxels that are significantly active for both of the contrast maps. We then applied a voxel correction of 25 contiguous voxels to these resulting conjunction maps (Gilead et al., 2014; Stillman et al., 2017). We conducted all pairwise cross-task conjunction analyses (e.g., far > near ∩ BW > color). We note that, though we used a relatively weaker correction threshold in our color task maps, since our primary analysis of interest takes the union of two maps, the effective threshold corresponds to $p < .00005$, uncorrected.

8 | RESULTS

8.1 | Regions of activation

8.1.1 | Overlap between distance and construal

As described in Stillman et al (2017), both high-level construal and distant future events activated regions in the mPFC and bilateral middle temporal gyrus, whereas low-level construal and near-future activated regions of the precuneus.

8.1.2 | Differences in color versus BW imagery (H1)

For the image generation task, which required participants to imagine BW versus color objects, we found several regions that preferentially activated in response to BW or color imagery (see Figure 2). Specifically, generating BW imagery engaged the dorsal

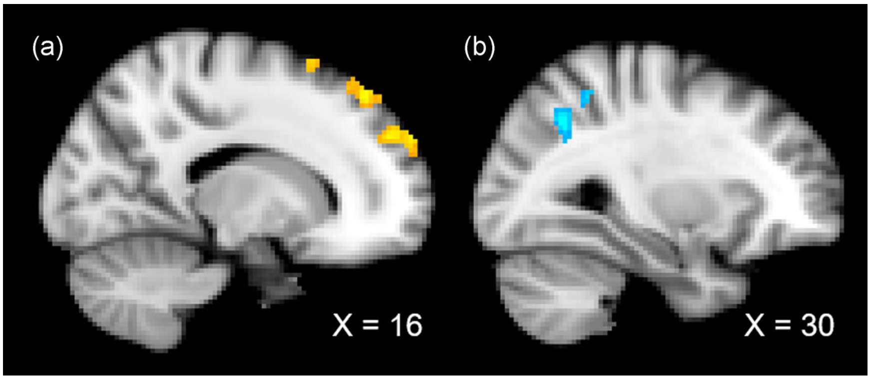

FIGURE 2 Contrast maps for (a) BW > color and (b) color > BW for the image generation task in which participants imagined objects and events in BW and color. Contrast maps shown at $p < .05$ uncorrected. BW, black-and-white [Color figure can be viewed at wileyonlinelibrary.com]

medial prefrontal cortex (dPFC), whereas generating color imagery preferentially engaged regions of the lateral occipital cortex (see Table 1). For the passive image-viewing task, however, there were no regions that survived correction—though we note this null finding is consistent with past work investigating activation differences in colors (Brouwer & Heeger, 2009). Subsequent analyses, therefore, focus on the conjunction between temporal imagery, construal level, and the image generation task in which participants actively generated images of objects in BW versus color.

8.2 | Conjunction analyses: overlap between distance, construal, and color of imagery (H2–4)

We next tested for common neural representation by examining the conjunction maps—maps that indicate where two or more contrast maps share common significant activation—for the visualization and the other two tasks. Consistent with our hypotheses, we found significant regions of overlap between those engaged in the generation of BW (relative to color) imagery and for those engaged in both thinking about distant (relative to near) future events (H2) and high-level (relative to low-level) construal (H3), respectively (see Figure 3). These regions appear to be centralized in the dPFC (see Table 2). Further, the conjunction of all three contrast maps revealed a single region that was significantly active across all three tasks in the dPFC (H4, see Figure 3). Finally, we find distinct overlapping regions engaged in the generation of color (relative to BW) imagery and in low-level (relative to high-level) construal within the superior parietal lobule (see Figure 3). There was, however, no overlapping regions engaged in the generation of color (relative to BW) imagery and thinking about temporally near (relative to distant) events.

TABLE 1 Clusters surviving correction for the contrast analyses of the visualization task

Overlap	Voxels	X	Y	Z	Region
BW > color	795	14	42	50	dPFC
Color > BW	157	14	−44	0	Cingulate gyrus
	108	30	−60	40	Lateral occipital cortex
	85	6	−66	20	Precuneus

Note: Whole-brain uncorrected at $p < .05$, followed by cluster correction threshold of 60 contiguous voxels. All coordinates listed in MNI space. Abbreviations: BW, black-and-white; MNI, Montreal-Neurological Institute.

9 | GENERAL DISCUSSION

Understanding the relationship between sensory experiences and consumers' construals, judgments, and behaviors is critical for effective marketing. In the present paper, we demonstrate how adopting a consumer neuroscience approach allows researchers greater insight into what people imagine (e.g., is the content monochrome vs. color), when they are more likely to imagine such content (e.g., temporal proximity vs. distance), and why (e.g., because of changes in construal level). Specifically, this study revealed that the presence or absence of color in consumer visualizations involve separable neural activity (H1), suggesting that the distinction between color versus BW may be a critical and variable component of consumers' visualizations. Further, and consistent with predictions from CLT, this study revealed that imagining distant future events and visualizing BW images activated common neural tissue (H2), providing initial neurological evidence consistent with CLT's proposition that the distant (vs. near) future and visualization of objects or events in BW (vs. color) share similar underlying processes. We further found common neural regions for high-level construal and the generation of BW imagery (H3), again providing initial neurological evidence that high-level construal, too, shares process commonalities with generating BW imagery. Finally, we found that imagining distant future events, engaging in high-level construal, and forming BW mental imagery all activated similar neural regions (H4). This finding of three-way neural overlap represents the first time that these three components have been demonstrated simultaneously, thus providing the most compelling evidence for the correspondence between BW, distance, and high-level construal. Further, we find that visualizing in color shared similar neural regions as low-level construal, though these overlaps were not apparent for imagining the near future. Finally, while we found our predicted results for the visualization task, we found no significant differentiation between passively viewing color versus BW images, a point we return to below.

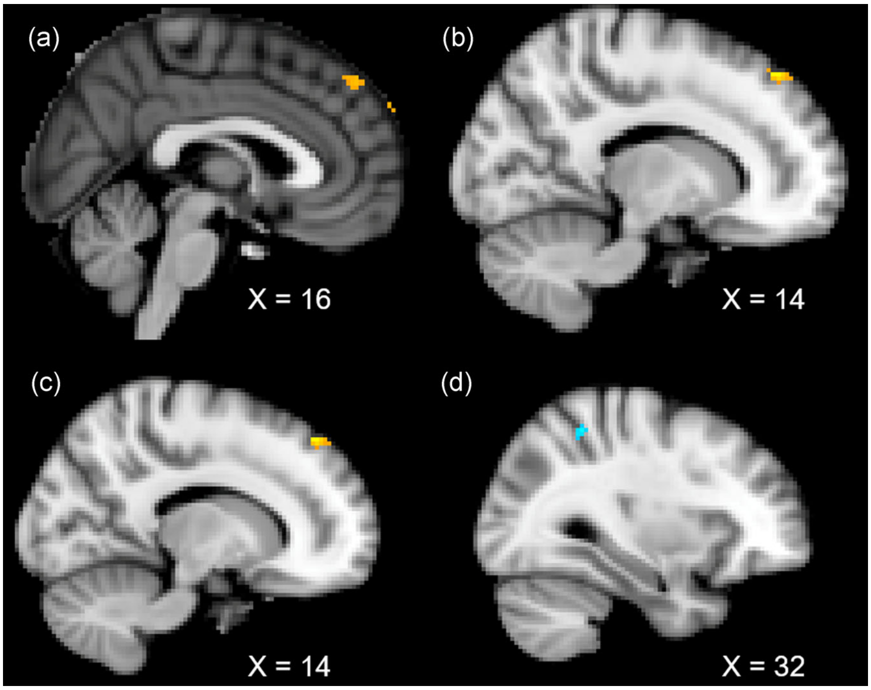

FIGURE 3 Conjunction analyses for (a) BW and high-level construal, (b) BW and distant future, (c) BW, high-level construal, and distant future, and (d) color and low-level construal trials. Clusters obtained via multiplying cluster corrected maps of 60 contiguous voxels—whole-brain corrected at $p < .001$ for the construal level and temporal imagery tasks, $p < .05$ for the image generation task—and then applying a cluster correction threshold of 25 voxels. BW, black-and-white [Color figure can be viewed at wileyonlinelibrary.com]

Overall, the present research provides a deeper insight into people's experiences with color in mental imagery and when these experiences are likely to occur. Importantly, the neuroscience methodology employed in this research provides novel insights that previous behavioral research could not (Lee et al., 2017). First, we provide stronger evidence for the distinction between BW versus color visualization—they activate distinct neural substrates. Second, we provide convergent evidence that people do indeed visualize the distant versus near future in BW versus color, respectively, bypassing many of the methodological concerns that could be leveled at published findings. Finally, our three-way neural overlap between BW imagery, distance, and high-level construal provides initial evidence for common cognitive processes across these three tasks. Of note, our findings are consistent with other research suggesting that the dPFC may be a critical area engaged in cognitive abstraction (see also, Badre, 2008; Badre & D'Esposito, 2007). Rather than reflect simple cognitive associations, the present fMRI findings provide initial evidence suggesting that BW (vs. color) sensory experiences and high-level (vs. low-level) construal share a much deeper, more fundamental relationship—that is, they share common underlying cognitive operations.

TABLE 2 Clusters that survived correction for the conjunction analyses

Conjunction	Voxels	X	Y	Z	Region
BW ∩ high-level construal	266	14	42	50	dPFC
	30	16	52	32	dPFC
BW ∩ distance	66	14	42	50	dPFC
Color ∩ low-level construal	33	32	−46	52	Superior parietal lobule
BW ∩ high-level construal ∩ distance	40	14	42	50	dPFC

Note: Clusters obtained via multiplying cluster corrected maps of 60 contiguous voxels—whole-brain corrected at $p < .001$ for the construal level and temporal imagery tasks, $p < .05$ for the color of imagery (image generation) task—and then applying a cluster correction threshold of 25 voxels. Conjunctions not listed had no clusters surviving correction. All coordinates listed in MNI space.
Abbreviations: BW, black-and-white; MNI, Montreal-Neurological Institute.

9.1 | Implications, limitations, and alternative explanations

9.1.1 | Passive viewing versus visualization

One notable result is that we did not find any significant neural differentiation in the passive image-viewing task. Thus, although asking participants to generate BW versus color mental images produced differences in neural activation in line with our hypotheses, simply viewing BW versus color pictures did not, even at relatively more liberal correction levels (i.e., $p < .05$ uncorrected). One possible explanation for this is, compared to actively imagining future events and visualizing scenes, the passive viewing task may not have elicited sufficient engagement from participants to produce robust differences in neural activation. One intriguing alternative possibility, however, is that there may be some important differences between processing external stimuli (viewing) and generating internal representations (visualization). This difference—of relatively greater impact of visualization versus viewing—may extend to domains beyond the presence or absence of color—something future research might explore. As marketing has tended to focus on passive viewing of images rather than visualization, the present results may suggest a need to re-direct research attention to the power of visualization. Although it is comparatively easier to have consumers view an image compared to visualize it, the present research may suggest that marketers must take seriously the notion that visualization is distinct from passive viewing. We expect and encourage future work in marketing further delineating the differences in visualizing and viewing.

9.1.2 | Near future and color

We had further predicted that regions associated with imagining near-future events would overlap with regions associated with the generation of color imagery and low-level construal. Although we found common neural regions between those involved in generating color imagery and low-level construal, we did not find any common regions between those involved in generating color imagery and imagining near-future events. One reason for the lack of clear neural overlap between the latter may be due to how people incorporate shape versus color information when forming mental images. As noted earlier, whereas BW images incorporate shape while ignoring color, color images incorporate both shape and color. This asymmetric incorporation of shape and color information may render it more difficult to observe the color/near-future/low-level construal overlaps that we predicted.

9.1.3 | Amount of thought

One might argue that consumers simply put less effort in imagining distant relative to near-future events, leading to more BW visual representations due to impoverishment. However, rather than simply finding less activation for BW relative to color imagery trials, we instead found different regions were activated. These data are more consistent with the argument that, rather than being less cognitively engaged, people were instead engaged in distinct cognitive processes when generating BW versus color imagery. Further, that BW imagery shared regions of overlap with both distant future imagery and high-level construal suggests that construal level may be the mediating factor for the enhanced similarity (either in process or content) between distant future and BW imagery. These findings not only suggest that distant future images are BW via a mechanism distinct from impoverishment (i.e., construal level), but also suggest that the images are not just "less colorful"—these data suggest that they are actually represented in BW. Thus, the neuroscience methodology that we advance provides novel insight and greater understanding into what exactly people are actually seeing when they imagine the distant versus near future and why.

9.1.4 | Distance and chromaticity

One potential alternative explanation for our results stems from the task instructions participants were provided for the image generation task; specifically "pretend you are seeing [the image] in a BW movie." It is possible that, as BW movies are associated with the distant past, this association—rather than a difference in visualization processes—accounts for our resulting overlaps. Although we cannot fully rule out this explanation, we do not believe it provides a full account of our findings for two reasons. First, we find that BW versus color visualization overlaps more extensively with high-level construal rather than temporal distance. One would expect exactly the opposite if our manipulation of BW visualization were redundant with distance. Second, while there is empirical support that color versus BW elicits low- versus high-level construal when holding distance constant (Study 5, Lee et al., 2017), there is no empirical support that we are aware of that manipulating BW versus color manipulates perceived distance. Thus, although it is always possible that this potential confound may partially account for our findings, we think it is highly unlikely given the available data.

9.1.5 | Color versus BW imagery

Beyond the differences between visualization and viewing, the neuroscience results suggest a number of potential next directions for visualization work. Investigating the regions activated for color versus BW imagery can inform our understanding of these visualizations. Specifically, color (relative to BW) visualizations activated regions of premotor cortex engaged in action observation and motor execution. This may suggest the importance of visualizing in color for products that require fine motor activity (e.g., kitchen appliances, computer mice and keyboards, etc.). Similarly, BW (relative to color) activated dPFC regions related to abstraction (Badre, 2008; Badre & D'Esposito, 2007) and decision-making (Elton, Smith, Parrish, & Boettiger, 2016; Lee et al., 2017; Northoff et al., 2006), as well as being implicated in the default-mode network (Coutinho et al., 2016; Di & Biswal, 2013; Elseoud et al., 2014; Spunt, Meyer, & Lieberman, 2015), which itself is critical for distance traversal (Stillman et al., 2017) and internally-generated cognition (Raichle, 2015). Together, this suggests the potential utility of BW visualizations for products that enable distance traversal (e.g., airlines, video conferencing, etc.), abstract concepts (e.g., art, theater), or that facilitate decision-making (e.g., planners, laptops, etc.). Though these predictions are speculative at this point, they serve to highlight how neuroscience data may begin to guide and constrain future hypotheses surrounding the nature and utility of visualization. These different functions of color versus BW visualization criticize the intuitive belief that BW imagery conveys less information and thus is of less marketing value than color imagery, and suggest the need to be more sensitive to various contexts in which BW versus color visualization may be more effective in delivering marketing messages.

10 | FUTURE DIRECTIONS

Although the current research focuses on visualization, these same methods can be applied to investigate other indirect sensory experiences, such as imagined audition and olfaction. Given the benefits of correspondence (or "fit") between marketing messages and consumer's internal representation of products (Han & Shavitt, 1994; Kim, Rao, & Lee, 2009; Lee et al., 2014; Shavitt, Lalwani, Zhang, & Torelli, 2006; Zhao, Dahl, & Hoeffler, 2014), more research on these internal sensory experiences using neuroscientific methods may greatly benefit marketers in practice.

Although this paper has focused on indirect sensory experiences—that is, sensory imagery—the same methods can be applied to examine direct sensory experiences as well. Research suggests that direct visual (e.g., Lee et al., 2014) and auditory experiences (Hansen & Melzner, 2014) can impact construal level. Construal level can also similarly impact people's sensory experiences such as taste (Hansen, 2019). Although generating paradigms to fit these phenomena to the scanner context may present some challenges, the insights from the present paper could be extended to these direct sensory experiences as well. The present findings also propose innovative questions about direct sensory experiences that could be tested empirically. For example, given their shared neural basis—that is, construal level, are certain auditory experiences associated with monochrome versus color imagery? Similarly, might monochrome versus color imagery impact people's taste perceptions? Understanding the shared neural mechanisms behind all of these phenomena systematically generates novel predictions yet unaddressed by empirical inquiry.

11 | CONCLUSION

The present work adopts a consumer neuroscience approach to investigate people's monochrome versus color imagery, when they are likely to "see" these images, and why. By addressing limitations of behavioral research, consumer neuroscience offers a complementary approach to assessing people's mental imagery. Given the importance of consumers' visualization on choice and consumption, we encourage further consumer neuroscience research to study the role of mental imagery in consumer behavior.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding authors upon request.

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Appendix A: Prompts and instructions used in the temporal distance and mental imagery task

Mental imagery instructions: "In this task you will be presented phrases describing objects or events. You will be asked to imagine these either in color or in black and white. For instance, for the black and white images, you may pretend you are seeing it in a black-and-white movie. Whether you are imagining in color or black and white will alternate every 6 phrases. Please do your best to create a mental image of each event in the prompted color scheme."

Temporal distance instructions: "In this task you will be presented with life activities. For each activity, you'll be prompted to imagine yourself performing the action either TOMORROW or 5 YEARS FROM NOW. Whether you are imagining the activity tomorrow versus a year from now will alternate every 5 activities. Please do your best to create a mental image of yourself engaging in that act at the time listed. We recognize it can sometimes be difficult to imagine yourself in the future, but please do your best."

Mental imagery	Temporal distance
A child reading	Grocery shopping
A man doing laundry	Driving a car
A girl washing dishes	Reading a book
A woman locking a door	Going on vacation
The line at the DMV	Having lunch with a friend
A girl brushing her teeth	Buying a car
Students listening to a lecture	Riding in an airplane
A man and a woman hugging	Calling a relative
A family eating dinner	Taking a shower
An old woman gardening	Going to the gym
A woman driving a car	Getting a haircut
A teacher speaking to a student	A job interview

A woman pulling weeds	Attending a wedding
A man chopping down a tree	Playing cards
A man measuring a room	Making dinner
Your friend painting her room	Buying coffee
A woman riding a roller-coaster	Writing a letter
A child climbing a tree	Cashing a check
A couple cooking dinner	Using an ATM
People working in an office	Doing laundry
Students studying at the library	Cleaning your room
A girl buying coffee	Washing dishes
Children trick-or-treating	Throwing a ball
A young man jogging	Hosting a party
A mother feeding her toddler	Composing an email
Pedestrians crossing the street	Attending a party
A group of people bowling	Going shopping
A basketball team practicing	Sending a text
Grocery shopping	Listening to music
A couple watching a movie	Reading a newspaper
A friend watching tv	Riding a bike
A baby sleeping	Going for a walk
A pair of shoes	Walking a dog
A bowl of cereal	Breaking your phone
A towtruck	Going on a date
A desk chair	Celebrating a friend's birthday
A ceiling fan	Taking a photo with a friend
A suitcase	Riding in a canoe

(Continues)

An airplane	Watching tv
A pair of pants	Going to a movie
A wedding band	Going to a concert
A bird	
A hot air balloon	
A jersey	
A peach	
A textbook	
A stovetop	
A rain jacket	
A cup of coffee	
A coffee table	
A tennis racket	
A trumpet	
Rollerblades	
A giraffe	
A fruit basket	
A bowl of spaghetti	
A hot dog	
A sofa	
A pair of earrings	
A cellphone	
A wardrobe	
A sled	
A pair of socks	
A caterpillar	