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Beyond visual experience: Brain activity reflecting sensory experiences implied by the product design

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Abstract: The present study investigates the neural mechanisms underlying consumer perception of products with visual designs that are accompanied by additional, implied sensory experiences. Functional Magnetic Resonance Imaging (fMRI) results showed that those brain areas involved in the actual perception of the relevant sensory stimuli were also involved in the sensory experience implied by the product design. The postcentral gyrus, SMA, and MT+ regions were associated with the kinesthetic experiences implied, whereas the insula was associated with the implied gustatory experiences. In addition, the caudate nucleus was involved in the participants' perception of designs implying the additional sensory experiences in general. The behavioral results echoed the neural results in the caudate nucleus. Participants preferred, remembered better, and showed greater buying intention for those products with implied sensory experiences compared to control stimuli, which were highly similar but lacked those features implying other sensory experiences. These results suggest that a product with a sensory experience implied by its design successfully recruits brain areas responsible for the corresponding sensory processes and also represents a positive reward to consumers.

Key words: product design, implied sense, fMRI.

We live in a world with plenty of products and buying options. Manufacturers are therefore constantly competing with each other to appeal to consumers. In this extremely competitive market, "the way a product looks" is often considered a key determinant of its fate (Bruce & Whitehead, 1988; Cooper & Kleinschmidt, 1987). As a result, there has been growing interest in the design of products (Bloch, 1995). In most products, the design is centered in the visual domain. However, to make a product look more interesting and appealing, designers sometimes introduce information from other sensory domains into the design. For example, when faced with a mission to create a package for banana-flavored milk, a designer has to come up with an idea to make the consumer's mouth water just by looking at it. Introducing visual features implying the flavor of a real ripe banana, such as a bright yellow color, the characteristic curvature of the stalk end, and just the right number of brown spots, might be a useful way to accomplish this mission (Figure 1a).

The success of a product design, and therefore of the designer who created it, relies on whether the designer's intention resonates with

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the consumers' mind. One way to tap into the minds of consumers is by monitoring their brain states. Given our current knowledge of the modularity of the sensory and motor brain areas, it is natural to wonder whether the design of a product can successfully convey a sensory experience in a modality other than the visual by examining the activity of the relevant areas of the brain. For example, the visualization of the package design of the banana-flavored milk with the concomitant activation of gustatory areas in the consumer brain indicates the success of the design and of its creator. This hypothesis is not far-fetched, as previous studies have shown that visual stimulus with an implied sensory experience can elicit the activation of the relevant sensory brain areas. For example, looking at appetizing food images activated brain areas in close proximity to the primary and secondary gustatory cortices (Simmons, Martin, & Barsalou, 2005), seeing visual notes accompanied by auditory imagery elicited the activation of the auditory cortices of trained musicians (Schürmann, Raij, Fujiki, & Hari, 2002), and observing familiar tools activated motor systems in the brain, including the premotor cortex (Grafton, Fadiga, Arbib, & Rizzolatti, 1997), the supplementary motor area (SMA; Amedi, Malach, Hendler, Peled, & Zohary, 2001) and the visual motion-sensitive area, MT+ (Amedi et al., 2001; Kable, Lease-Spellmeyer, & Chatterjee, 2002). These findings suggest that, from a purely visual stimulus, the brain can produce sensory experiences other than the visual.

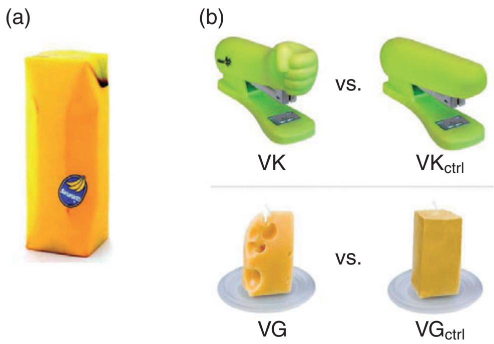

Figure 1 (a) Example of product with a design that implies a gustatory experience. The visual features implying a real ripe banana include the specific color and shape introduced in the package design of banana-flavored milk. (b) Top: Examples of experimental and control stimuli. An image of a stapler with an implied kinesthetic experience (to bang with fist, VK) and a matching control stimulus without the implied kinesthetic experience (VK_{ctrl}). Bottom: An image of a candle with an implied gustatory experience (taste and smell of cheese, VG) and matching control stimulus without the implied gustatory experience (VG_{ctrl}).

In addition to the activation of specific brain areas relevant to the implied sensory experience, there might be other brain areas activated by the visualization of a product design with an implied sensory feature, regardless of its modality. Of particular interest is the brain network involved in processing and anticipating rewards. If a design with an implied sense indeed activates reward-related brain regions, such a design might be enjoyed, preferred, and considered as a positive reward by consumers. This hypothesis is supported by previous studies showing that consumer choice is associated with the activation of reward-related brain regions, including the caudate nucleus (Berns, Capra, Moore, & Noussair, 2010; Sharot, De Martino, & Dolan, 2009; Weber, Aholt, Neuhaus, Trautner, Elger, & Teichert, 2007).

Inspired by these previous findings, here we investigate two related questions: (a) whether products with a visual design that also implies a sensory experience in other domains elicit the activation of the corresponding brain areas; and (b) whether there exists a shared neural mechanism for product designs with implied sensory experiences across different sensory modalities. To answer these questions, we selected images of products with visual designs implying either kinesthetic (VK) or gustatory (VG) sensory experiences as experimental stimuli. To determine the brain areas specifically activated by these designs, we created control stimuli, that is, VK_{ctrl} and VG_{ctrl}, respectively, by removing the visual features implying additional sensory experiences from the experimental stimuli while maintaining other aspects as similar (Figure 1b). By comparing the brain activity involved in the perception of the experimental stimuli with that involved in the perception of the control stimuli, we examined if VG and VK elicit greater activation of, respectively, the gustatory cortices and kinesthesia-related brain regions than VG_{ctrl} and VK_{ctrl}. In addition, conjunction analyses were performed to determine those brain regions commonly associated with the "VK vs. VK_{ctrl}" contrast and the "VG vs. VG_{ctrl}" contrast. The behavioral responses of participants to the experimental stimuli, in terms of preference, memory, and buying intention, were compared with their neural responses.

Methods

Participants

A total of 23 healthy female undergraduate students (mean age = 21.4 ± 1.8 years) participated in the experiment. We tested only female students deliberately due to their overall higher aesthetic sensitiveness and greater interest in the design aspects of products than male students (Eurich & Caroll, 1931). All participants gave their written informed consent, and the experiment was approved by the Korea University Institutional Review Board.

Stimuli and procedure

The experimental stimuli consisted of two types of color images showing the design of a product with features implying additional sensory experience: (a) 20 images with an implied kinesthetic experience (VK); and (b) 20 images with an implied gustatory experience (VG). Forty matching control stimuli were created carefully by modifying the experimental stimuli: those visual features responsible for the implied sensory experience were removed while all the other aspects remained similar to the experimental stimuli. As a result, the control stimuli were supposed to elicit little or no kinesthetic (VK_{ctrl}) or gustatory (VG_{ctrl}) experience. The two pairs of example stimuli are shown in Figure 1b.

VK and VK_{ctrl} were presented in one session and VG and VG_{ctrl} were presented in another, separate session. The order of sessions was counterbalanced among the participants. The order of stimuli was pseudo-randomized within a session. At the beginning of a session, participants read the written instruction as follows: "You will look at a series of pictures of products that were designed by foreign designers and are about to be introduced into the Korean market. Please pay attention to each and every one of them. There will be some tests after scanning." Each of the 40 trials (20 experimental and 20 control) within a session began with a fixation cross (2–4 s), followed by the presentation of an image of a product (1 s). Participants viewed the images passively. The total duration of one session was 3 minutes and 50 seconds (Figure 2).

Post-scanning behavioral tests

Preference test. To explore if participants prefer those products with a design that implied an additional sensory experience, we asked participants to rate the degree of preference for each stimulus using a 7-point Likert scale (1 being "do not prefer at all" and 7 being "absolutely prefer"). Half of the stimuli presented during scanning (40 stimuli: 10 VK, 10 VK_{ctrl}, 10 VG, and 10 VG_{ctrl}) were selected and presented to each participant.

Memory test. To test if participants remember those products with a design implying an additional sensory experience better than those without it, we asked participants to indicate whether they saw the presented image in the scanner or not. A total of 80 stimuli were presented to each participant, half of which corresponded to those viewed in the scanner (40 stimuli: 10 VK, 10 VK_{ctrl}, 10 VG, and 10 VG_{ctrl}) and half of which consisted of new stimuli (40 stimuli: 10 VK, 10 VK_{ctrl}, 10 VG, and 10 VG_{ctrl}).

Buying intention test. To test if participants would like to purchase those products with an additional sensory experience implied, if those products were introduced into the market, we asked them to rate their buying intention for each stimulus using a 7-point Likert scale (1 being "do not want to buy at all", and 7 being "definitely want to buy"). Half of the stimuli presented during scanning (40 stimuli: 10 VK, 10 VK_{ctrl}, 10 VG, and 10 VG_{ctrl}) were selected and presented to each participant.

fMRI data acquisition and analysis

The experiment was conducted at the MR Research Center at the Korea Advanced Institute of Science and Technology using a 3.0 T Forte MRI scanner (ISOL. Tech, Oxford OR, 63) equipped with a standard head coil. Structural images were obtained using a standard T1-weighted pulse sequence. Functional images were obtained using a two-shot T2*-weighted spiral-scan pulse sequence (TR = 2000 ms, TE = 30 ms, flip angle = 80, FOV = 240 mm). Twenty-four axial slices were acquired in an interleaved order covering the whole brain with a slice thickness of 4 mm with no interslice gap.

Reconstructed images were corrected for small head movements using a six-parameter automated image registration (AIR) algorithm (Woods, Cherry, & Mazziotta, 1992). Due to poor brain images with head motion artifact, data from three of the participants were excluded from further analysis. Data were analyzed with the statistical parametric mapping software package (SPM5, Wellcome Department of Cognitive Neurology, London, UK). Image preprocessing included realignment, slice-time correction, spatial normalization, and smoothing with an 8 mm (full-width half-maximum) Gaussian kernel for the analysis at the group level (Friston, Ashburner, Frith, Poline, Heather, & Frackowiak, 1995). For statistical analysis, each time series was convolved with a hemodynamic response function to create a regressor for the contrast between the trials and the intertrial fixation periods with varied durations. Condition effects were then assessed with event-related contrasts comparing neural activity for the experimental and for the control trials. Conjunction analysis was performed with the contrast between VK and VK_{ctrl} and the contrast between VG and VG_{ctrl} to identify the brain areas commonly activated by those product designs that implied additional sensory experiences. Separate design matrices were generated for each participant to identify the brain regions in which the neural activation level was correlated with postscanning preference rating scores for VG and VK.

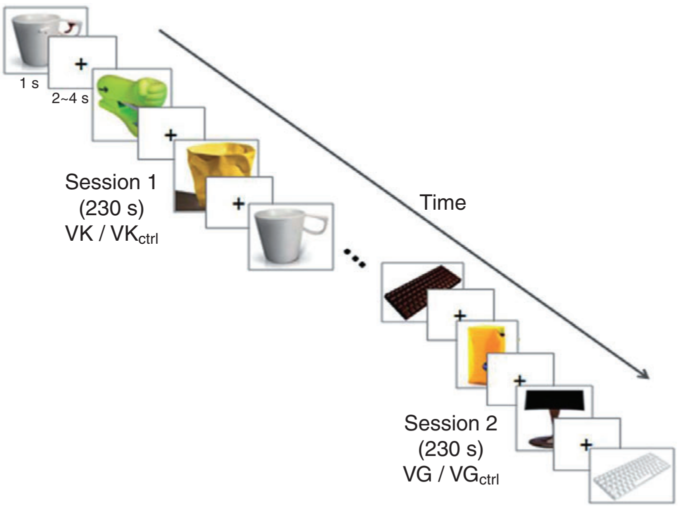

Figure 2 Schematics of the scanning procedure. Each session comprised a series of 40 stimuli, that is, 20 experimental and 20 control, each presented for 1 s with varied fixation durations (2–4 s). One session contained VK and VK_{ctrl} stimuli and the other session contained VG and VG_{ctrl} stimuli. The session order was counterbalanced among the participants.

Table 1 Brain areas associated with a specific sensory modality implied in a product design

Condition	Brain area	Hemisphere	Coordinates			Z-score
			x	y	z	
VK – VK_{ctrl}	Middle temporal gyrus	Left	–38	–74	–20	4.52
	Postcentral gyrus	Right	22	–28	58	4.10
	Supplementary motor area	Left	–28	–4	64	3.87
	Hippocampus	Left	–24	–16	–18	3.78
	Occipito-temporal gyrus	Left	–46	–72	–4	3.69
	Caudate nucleus	Right	14	–8	24	3.19
VG – VG_{ctrl}	Insula	Right	36	0	4	3.25
	Caudate nucleus	Right	14	–8	24	3.08

Note. x, y, z = Talairach stereotaxic coordinates of the peak of the activated clusters.

Results

Brain areas associated with implied sense in a specific modality in product design

To identify the brain areas specifically associated with the perception of the visual design with an implied kinesthetic experience, we compared neural responses to VK and VK_{ctrl}. Table 1 lists those brain regions that showed greater activation in the VK than in the VK_{ctrl} condition. The identified areas include the middle temporal gyrus, the SMA, the hippocampus, the occipito-temporal gyrus (OTG) in close proximity to the visual motion sensitive area, MT+ (Wilms, Eickhoff, Specht, Amunts, Shah, Malikovic, & Fink, 2005), in the left hemisphere, and the postcentral gyrus and the caudate nucleus in the right hemisphere. Some of those activation sites are shown in Figure 3. The region of interest (ROI) analyses demonstrated that these areas showed increased activation in the VK condition, whereas no such increase was found in the VK_{ctrl} condition.

To identify the brain areas specifically associated with the perception of design with an implied gustatory experience, we compared neural responses to VG and VG_{ctrl}. Table 1 lists the regions showing greater activation in the VG than in the VG_{ctrl} condition. The areas identified include the insula and the caudate nucleus in the right hemisphere. The region of interest (ROI) analysis demonstrated that the insula showed an increased activation in the VG condition, whereas no such increase was found in the VG_{ctrl} condition (Figure 4a). Likewise, there was increased activation in the caudate nucleus in the VG condition (Figure 4b).

Brain areas commonly associated with implied sense in different modalities in product design

To identify the brain regions that are commonly involved in the perception of designs with implied experiences in different sensory modalities, we performed a conjunction analysis. Specifically, we searched for voxels that showed greater activation for VK than VK_{ctrl} and for VG than VG_{ctrl} ([VK – VK_{ctrl}] and [VG – VG_{ctrl}]). The right caudate nucleus was found to be associated with both VK relative to VK_{ctrl} and VG relative to VG_{ctrl}. Voxels of this area are shown in yellow in Figure 5a, which is the intersection between the activation clusters identified by individual contrasts; the voxels showing increased response to VK than VK_{ctrl} are shown in green, whereas those showing increased response to VG than VG_{ctrl} are shown in red.

Behavioral responses to the product design with vs. without implied sense

Preference test. Participants preferred product designs with an implied sense, mean = 4.98, over those without it, mean = 3.72. This difference in the preference rating was statistically significant, paired *t*-test: $t = 7.108$, $p < .01$.

Memory test. The performance of participants in the postscanning memory test showed a higher old/new discrimination accuracy for those product designs with an implied sense, mean = 87.75%, than for those without it, mean = 81.7%. This difference was statistically significant, paired t-test: $t = 2.651$, $p < .01$.

Buying intention test. Participants showed a significantly greater intention to purchase those products with a design accompanied by additional sensory experiences, mean = 4.31, than those without such design aspects, mean = 4.04; paired t-test: $t = 2.223$, $p < .05$.

Brain areas positively correlated with degree of preference for the product design with implied sense

To examine whether those brain regions that are involved in the perception of designs with implied sense exhibit positively correlated BOLD activity with postscanning preference rating scores, we performed additional parametric analyses. The areas showing positive correlation with postscanning preference rating scores for VG included the right caudate nucleus, which was in proximity to the brain region commonly associated with VG and VK (Figure 5b). The analyses didn't reveal the same region as correlated with preference rating scores for VK. Instead, the right putamen was identified as positively correlated with the degree of preference for VK.

Discussion

The fMRI results showed that the brain areas involved in the perception of the relevant sensory stimuli were also involved in processing the sensory experience implied by the visual design of the products. Regions that showed

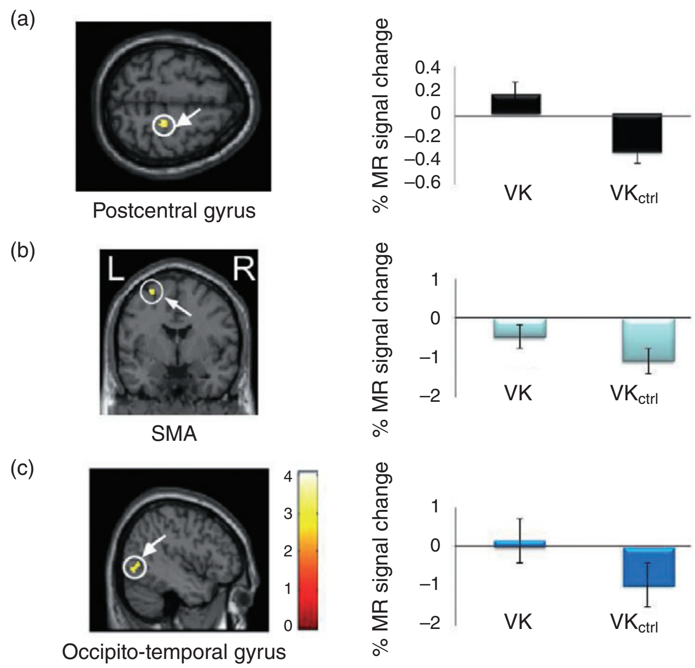

Figure 3 Brain areas associated to kinesthetic perception that showed increased response to the VK compared with the VK_{ctrl} condition ($p < .001$). The color bar indicates the Z scores of the peak activation. (a) Right postcentral gyrus ($x, y, z = 22, –28, 58$; $Z = 4.10$, $p < .001$). (b) Left supplementary motor area (SMA) ($x, y, z = –28, –4, 64$; $Z = 3.87$, $p < .001$). (c) Left occipito-temporal gyrus ($x, y, z = –46, –72, –4$; $Z = 3.69$, $p < .001$).

greater activation for the VK than for the VK_{ctrl} stimuli included the middle temporal gyrus, postcentral gyrus, SMA, and OTG areas. Among those activated regions, the postcentral gyrus is the primary somatosensory area, a brain center for the bodily sensations, including kinesthesia, and the SMA is also known to be involved in kinesthetic experience (Bodegård, Geyer, Herath, Grefkes, Zilles, & Roland, 2003; Roland, 1987). In addition, the regions that showed greater activation for VG than VG_{ctrl} included the insula, a part of which is known as the primary gustatory cortex (Faurion, Cerf, Le Bihan, & Pilliasa, 1998; Small, Zald, Jones-Gotman, Zatorre, Pardo, Frey, & Petrides, 1999).

The increased activation of the kinesthetic/gustatory sensory brain areas, despite a lack of physical stimulation, might be due to the mental imagery produced by participants when looking at images of designs that implied these sensory experiences. For example, a participant might have imagined himself punching the stapler when viewing the VK stimulus in

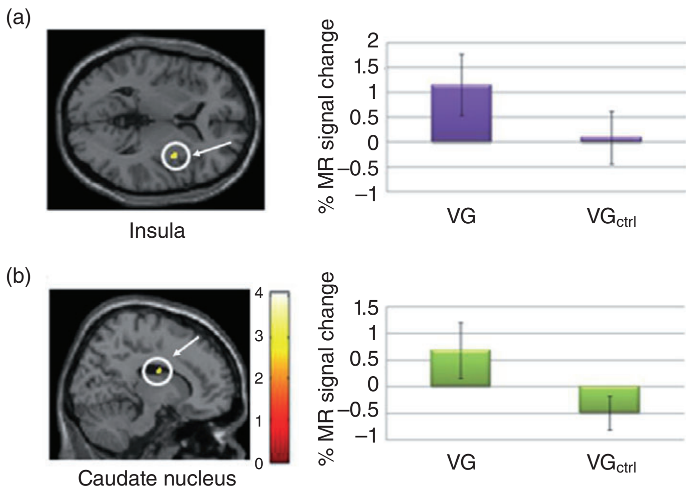

Figure 4 Brain areas showing increased response to the VG compared with the VG_{ctrl} condition. The color bar indicates the Z scores of the peak activation. (a) Right insula (x, y, z = 36, 0, 4; Z = 3.25, p < .005). (b) Right caudate nucleus (x, y, z = 14, –8, 24; Z = 3.08, p < .005).

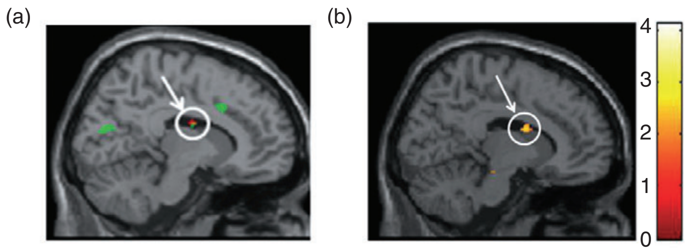

Figure 5 (a) The caudate nucleus commonly associated with an implied sensory experience in different modalities as elicited by a product design, which also shows positive correlation with degree of preference. Results from blob analyses showing that activation in the caudate nucleus was also observed in both individual contrasts, namely VK – VK_{ctrl} (shown in green) and VG – VG_{ctrl} (shown in red). Voxels shown in yellow represent the spatial overlap between the two individual contrasts. (b) An anterior part of the caudate nucleus showing positive correlation with preference rating scores for VG stimuli (x, y, z = 12, 2, 20; Z = 2.50, p < .01). The color bar indicates the Z scores of the peak activation.

Figure 1b. Indeed, the activated regions revealed by the contrast VK vs. VK_{ctrl} have been shown to be involved in "unreal" motion experiences. Previous studies have suggested that SMA is associated with motor imagery (Binkfski, Amunts, Stephan, Posse, Schormann, Freund, Zillers, & Seits, 2000; Roland, Larsen, Lassen, & Skinhøj, 1980; Stephan, Fink, Passingham, Sillbersweig, Ceballos-Baumann, Frith, & Frackowiak, 1995). Also, the visual motion-sensitive area, MT+, located in close proximity to the OTG area we found, is well known for its involvement in visual imagery of motion (Goebel, Khorram-Sefat, Muckli, Hacker, & Singer, 1998; Seurinck, de Lange, Achten, & Vingerhoets, 2011). The activation of the insula, revealed by the contrast VG vs. VG_{ctrl}, can also be attributed to its involvement in gustatory imagery (Levy, Henkin, Lin, Finley, & Schellinger, 1999; Ogawa, 1994).

This imagery hypothesis does not undermine the success of products with a visual design accompanied by implied sensory experiences, or of their designers. Participants in the current study viewed stimuli passively without being engaged in any task requiring mental imagery. If VK stimuli led participants to voluntarily imagine they were using the product, and if VG stimuli made participants imagine that they were tasting the implied food more than the VG_{ctrl} stimuli did, then this indicates that the designer's intentions resonated well with the people who viewed the designed product (see Kim & Blake, 2007 for a similar argument).

One could argue that the observed activation of the insula was mainly due to the inclusion of some food products as VG stimuli, such as the banana-flavored milk shown in Figure 1a (see the Appendix for the complete list of the stimuli: #9, 14, 18, 20 are food packages). However, the matching control stimuli (VG_{ctrl}) were also food products, making this possibility unlikely. To confirm that the insula activation was not driven by the images of the edible item, we performed an additional analysis by excluding the four trials related to those items from the event-related analysis. The removal of the real food-related stimuli did not invalidate the activation in the insula.

The fMRI results also showed that the caudate nucleus was identified both by the VK vs. VK_{ctrl} and the VG vs. VG_{ctrl} contrasts. The activation of the caudate nucleus revealed by the VK vs. VK_{ctrl} contrast can be interpreted as being specifically related to the implied kinesthetic experience. The activation of this region has been previously reported during mental simulation of grasping objects in a PET study (Decety, Perani, Jeannerod, Bettinardi, Tadary, Woods, Mazziotta, & Fazio, 1994), and during motor imagery and mental simulation in an fMRI study (Gerardin, Sirigu, Lehericy, Polin, Garymard, Marsault, Agid, & Le Bihan, 2000). Likewise, the activation of the caudate nucleus revealed by the VG vs. VG_{ctrl} contrast can be related to the gustatory experience implied by the designs presented to the subjects. The activation of this region has been previously associated with food cravings (Pelchat, Johnson, Chan, Valdez, & Ragland, 2004) and foods with strong positive valence, such as chocolates (Small, Zatorre, Dagher, Evans, & Jones-Gotman, 2001). However, it is also plausible that the activation of the caudate nucleus reflects the observation that products with additional sensory experiences implied are generally considered as positive rewards by those viewing them. For example, the dorsal part of the striatum has been involved in reward-based learning during rapid target detection to obtain a reward (Knutson, Adams, Fong, & Hommer, 2001; Knutson, Westdorp, Kaiser, & Hommer, 2000) and during anticipation of rewards determined by the action of participants (Delgado, Miller, Inati, & Phelps, 2005; Elliott, Friston, & Dolan, 2000; Tricomi, Delgado, & Fiez, 2004). Furthermore, this brain area has also been associated with consumer choice (Berns et al., 2010; Sharot et al., 2009; Weber et al., 2007).

Echoing the results from the brain imaging, the behavioral results showed that participants preferred, remembered better, and showed greater buying intentions for the experimental than for the control products, suggesting that designs implying additional sensory experiences are enjoyed by the participants. More importantly, the results showed a positive correlation between participants' preference rating responses for VG stimuli and the neural activity in the right caudate nucleus, the area associated with product design with implied sense in general. This implies that the activation in the caudate nucleus found in our fMRI experiment reflects the participants' preference for product designs with implied sensory experiences. We are baffled by the failure to identify a correlation of this region with participants' preference rating responses for VK. However, it should be noted that only a half of the stimuli presented during scanning were utilized during the post-scanning behavioral tests. A full utilization of the complete list of the VK and VG stimuli in the preference rating may provide a clearer picture on the correlation between the neural and behavioral responses.

The greater preference and buying intention for VK and VG, however, might be related to the different degree of completion between the experimental and the control stimuli. The control stimuli were created by modifying the experimental stimuli, which comprised images of existing products. The control stimuli, therefore, might be naturally viewed as being less complete than the experimental stimuli. Even though the control stimuli were generated by professional graphic designers and looked as real as the experimental stimuli, possible differences in their degree of completeness remain a potentially confounding factor in the current study. For the complete list of the stimuli, see the Appendix.

In summary, this study showed that the brain areas involved in the perception of the relevant sensory stimuli are also involved in the sensory experience implied by product designs. The postcentral gyrus, SMA, and MT+ regions were associated with the implied kinesthetic experiences, whereas the insula was associated the implied gustatory experiences. In addition, the caudate nucleus was in general involved in the participants' perception of designs with additional sensory experiences implied, which is suggestive of participants' preference for these designs. In future work, it would be important to compare the spatial location of the brain regions involved in implied and real sensory experiences.

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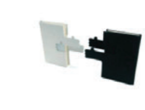
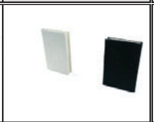
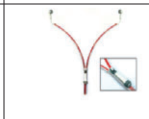
Appendix

Complete list of the stimulus images.

(a) **VG and VG_{ctrl}**

#	Item Description	VG	VG_{ctrl}	#	Item Description	VG	VG_{ctrl}
1	Hand cream			11	Band-aid		
2	Candle			12	Hand cream		
3	Liquid soap			13	Plate		
4	Mirror			14	Banana milk		
5	Handbag			15	Blusher		
6	Plate			16	Crayon		
7	Blusher			17	Candle		
8	Container			18	Strawberry milk		
9	Orange juice			19	Plates		
10	Keyboard			20	Strawberry icecream		

(b) **VK and VK_{ctrl}**

#	Item Description	VK	VK_{ctrl}	#	Item Description	VK	VK_{ctrl}
1	Notebook			11	Cup		
2	Night stand			12	Bottle		
3	Tissue case			13	Plate		
4	Stapler			14	USB		
5	Light switch			15	Night stand		
6	Cup			16	Remote controller		
7	Ash tray			17	Earphones		
8	Waste basket			18	Cup		
9	Tissue case			19	Pen		
10	Bottle			20	Cup