Does the cosmetic stimulation of brain regions involved in multiple senses amplify multisensory perception? "Beyond their traditional benefits, cosmetics as potential sensory transformation tools."

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Abstract.

The senses of sight, touch, and smell perceive cosmetic makeup, product comfort, fragrance, and other design elements. The brain processes these perceptions to determine attractiveness. Thus, understanding cognition, the final value judgment in the brain, is important for enhancing user experiences with cosmetics.

Our research has shown that a specific brain region, the anterior prefrontal cortex (aPFC), is activated when recognizing visual attractiveness. Moreover, this area is also activated when recognizing attractiveness through other senses, suggesting that stimulating the aPFC via one sense could influence the attractiveness impression across multiple senses. Therefore, we hypothesized that the aPFC is a key region that is common across the senses in the cognition of attractiveness.

We conducted an experiment to verify this idea, which confirmed that the experimental activation of the aPFC through transcranial magnetic stimulation enhanced attractiveness impressions across multiple senses. Using fMRI, we found that touching cosmetics with a specific physical property effectively activated the aPFC. Furthermore, touching such cosmetics enhanced the attractiveness impressions from senses beyond touch cross-modally.

These findings suggest that cosmetics could be given a new sensory function as sensory transformation tools, which renders the daily experiences perceived by the five senses more attractive.

Keywords: Brain science; Cognition of attractiveness; Brain stimulation; Sensory transformation; Skincare product; five senses

Introduction.

Cosmetics not only adorn the face and skin and provide a healthy appearance but also offer sensory values, such as pleasantness and excitement, when used. We believe that by understanding this *feeling* mechanism from the perspective of brain science, new sensory functions in cosmetics can be created to enhance user experience.

Makeup engages the sense of sight, the feel of a product engages touch, and fragrance engages smell. Generally, cosmetic development has focused on these pairings, thus, improving functions mainly through surface chemistry and dermatology, and enhancing the user experience by psychologically evaluating the attractiveness of the texture, fragrance, and the improved skin appearance from using the cosmetics. In general cosmetics development, reconsidering the mechanism of the cognition of attractiveness from the perspective of brain science, the brain perceives and processes information input from each sensory organ (e.g., sight and touch), which leads to a sensory value judgment of attractiveness. Understanding the cognitive processes that make these final sensory value judgments could change the traditionally paired relationship-focused cosmetic development and introduce new sensory functions to cosmetics.

We previously conducted brain function experiments using 8k visual stimuli to accurately replicate real-world brain responses. These experiments revealed that the anterior prefrontal cortex (aPFC) is activated during the recognition of visual attractiveness [1] (Figure 1a). The previous literature also posited that the aPFC is activated when attractiveness is perceived from the input of the senses apart from sight, that is, touch [2], smell [3], taste [4], and hearing [5] (Figure 1b). Based on these findings, the current study hypothesized that the aPFC is a key region that is common to the recognition of attractiveness impression across the senses (Figure 1c). If this hypothesis is correct, then activating the aPFC through one type of sense should enhance the attractiveness impression of the other senses. For example, touching cosmetics may enhance the visual attractiveness impression. In other words, the study proposes that cosmetics could be given a new sensory functions as tools for sensory transformation.

We conducted a research plan that included several steps to verify this idea. To add the function of a sensory transformation tool to cosmetics, we first needed to verify the hypothesis that aPFC activation influences attractiveness impressions across the senses (Figure 1d). We then tested whether or not sensory stimulation by cosmetics, such as tactile stimulation from touching cosmetics, can induce aPFC activation (Figure 1e). Finally, we intended to confirm whether or not touching cosmetics, if it can induce aPFC activation, can enhance the attractiveness impressions of the other senses apart from touch (Figure 1f). Specifically, in Experiment 1, we used transcranial magnetic stimulation (TMS) to precisely target and stimulate the aPFC. In this study, to explore the possibility of improving multiple sensory-derived attractiveness impressions by activating the aPFC, we evaluated the attractiveness impressions perceived by visual and tactile senses (Figure 1d). This study evaluated the attractiveness impressions perceived through sight and touch to explore the potential of enhancing the attractiveness impressions of multiple senses through aPFC activation. For visual evaluation, we used two types of images, namely, faces and landscapes, to confirm whether or not aPFC activation influences attractiveness impressions regardless of the type of object. For tactile evaluation, we used cosmetics. In Experiment 2, given that the aPFC is activated after touching objects that feel pleasant [2], we focused on the physical properties related to the pleasant feel of cosmetics and confirmed the degree of aPFC activation induced when touching cosmetics with different physical properties using an fMRI scanner (Figure 1e). Finally, for Experiment 3, we confirmed the impact of cosmetics with high levels of aPFC-activation–induction ability on visual attractiveness impressions (Figure 1f).

Based on these findings, we examined the potential of giving cosmetics the function of a sensory transformation tool that influences the attractiveness impressions of multiple senses.

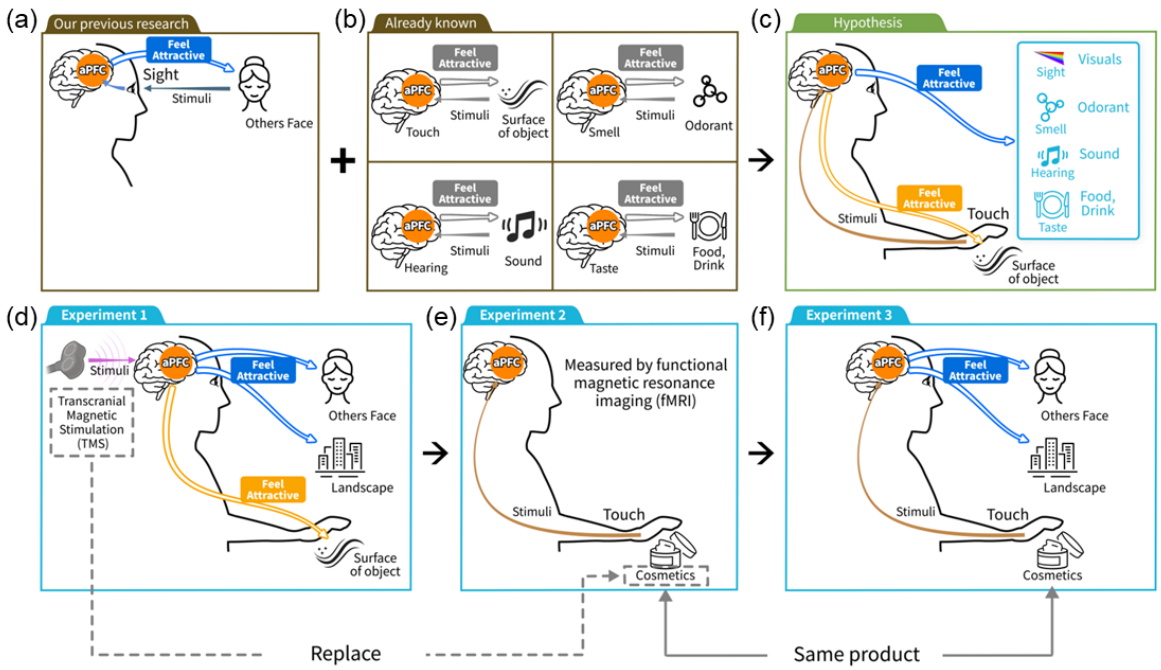

Figure 1. Schematic of the study

(a) Relationship between vision and aPFC, as shown in our previous research. (b) Already known relationship between multiple senses and aPFC. (c) Relationship between multiple senses and aPFC, which is the hypothesis of the study. (d) Schematic of Experiment 1. (e) Schematic of experiment 2. (f) Schematic of experiment 3.

Materials and Methods.

Experiment 1: <u>Verification of the effect of aPFC activation via transcranial magnetic stimulation (TMS) on enhancing the attractive impressions of multiple senses (Figure 1d).</u>

Participants:

The study recruited 16 Japanese women aged 20 to 59 years with an even distribution across age groups.

Intervention Stimulation of transcranial magnetic stimulation (TMS):

Figure 2a depicts the brain stimulation environment in which the brain stimulation method used was TMS. The TMS device was the DuoMAG XT-100 (DEYMED Diagnostic s.r.o., Czechia), while the stimulation coil was the DM70BF-LQC (DEYMED Diagnostic s.r.o., Czechia). In brain stimulation, precisely pinpointing the brain region to be stimulated is crucial. Therefore, the study used a magnetic stimulation navigation system (Brainsight, Rogue Research, Inc., Canada) to immobilize the heads of the participants to align the target brain area. Afterward, the spatial information of the participant and coil trackers was obtained using the position sensor camera, which enabled the identification of the location of the stimulation coil in relation to the position of the brain. The position of the brain was then aligned to the unique brain shape of the participants using MRI images that were previously obtained.

Figure 2b illustrates the brain stimulation conditions. We followed the intermittent theta burst stimulation (iTBS) protocol reported by Huang et al. [6] to activate the brain region. We performed theta burst stimulation for 2 s followed by an 8-second pause for a total of 600 pulses of stimulation. The iTBS protocol was performed over the left anterior prefrontal cortex (left-aPFC, Brodmann area 10, Montreal Neurological Institute (MNI) coordinates = −23, 55, 4) according to BioImage Suite Web [7]. A figure-eight-shaped coil was placed parallel to the head with its center on the left-aPFC for the stimulation condition. The same coil was used for the sham stimulation, which was set as the control, but placed perpendicular to the head with the coil tilted at 90°. In this manner, only one part of the coil was on the left-aPFC to ensure that no actual stimulation occurs. The iTBS and sham conditions were performed in a random order for each participant with counterbalancing. The interval between each condition was set at 60 min based on papers that report that the effects of iTBS excitation last up to 60 min after stimulation [6, 8]. The stimulation intensity for the iTBS protocol was set to 80% of the active motor threshold (AMT). The stimulation intensity was determined using motor evoked potentials (MEPs). The stimulation site for MEP measurement was the left primary motor cortex hand area, and the right first dorsal interosseous muscle was used for recording. The AMT was defined as the intensity that induced 100 µV MEPs in more than 50% of trials during slight voluntary muscle contraction. The same intensity was used for the sham condition. After the magnetic stimulation of the left-aPFC, the study evaluated visual or tactile impressions within the duration of the stimulation effect. The experiment followed the guidelines on the safety of TMS [9].

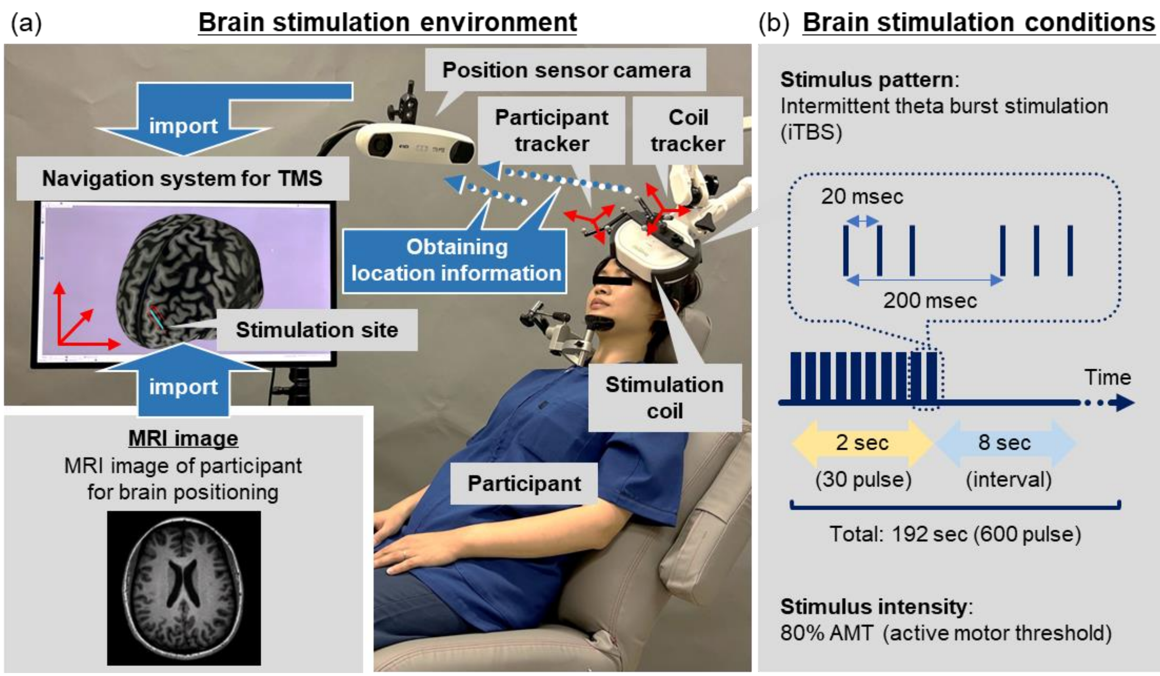

Figure 2. Brain stimulation environment and conditions

Brain stimulation (a) environment and (b) conditions.

Creation of Facial images for Visual Impression Evaluation:

The study recruited 80 Japanese women aged 20 to 69 years as facial image models. To capture the facial images, an 8K camera (Monstro, Red Digital Cinema Camera Company, CA, USA) was used to take frontal photos with neutral facial expression under consistent lighting conditions. The display size of the facial images was set to fit within a visual angle of 8°, which can be viewed centrally from 1,015 mm away on an 8K 32-inch display. The facial images were placed in the center of the screen.

Selection of Landscape Images for Visual Impression Evaluation:

The landscape images consisted of 80 images of landscapes in Japan, which were equally divided into urban and natural sceneries. For natural landscapes, the images were equally divided among the four seasons, namely, spring, summer, autumn, and winter. The display size of the landscape images was set to a 16:9 aspect ratio (7,680 × 4,320 pixels). The images were resized to match this aspect ratio, which ensures a consistent resolution. The landscape images were placed in the center of the screen. For resolution adjustment, the study used Photoshop 23.0.1 (Adobe, Inc., CA, USA).

Visual Impression Evaluation:

Figure 3a presents the flow of one trial for the evaluation of the impression of facial images. A fixation point was displayed for 1,000 ms followed by the display of the facial image for 1,000 ms. Each participant was shown the facial images of each model and asked to rate attractiveness using a six-point scale from 1 = Not attractive to 6 = Very attractive. Each participant repeated this process for 80 trials after iTBS stimulation and 80 trials after sham stimulation for a total of 160 trials. The order of the presentation of the facial images was randomized.

Figure 3b indicates the flow of one trial for evaluating the impression of landscape images. The testing was conducted under the same conditions as the impression evaluation of the facial images. Moreover, the order of the landscape images presented was randomized.

The distance between the display of the facial and landscape images and the participants was set to 1,015 mm. The display used for presenting the facial and landscape images was an 8K 32-inch display (8M-B32C1, SHARP Corp., Japan), and the experiment was controlled using E-Prime 3.0 (Psychology Software Tools, Inc., PA, USA).

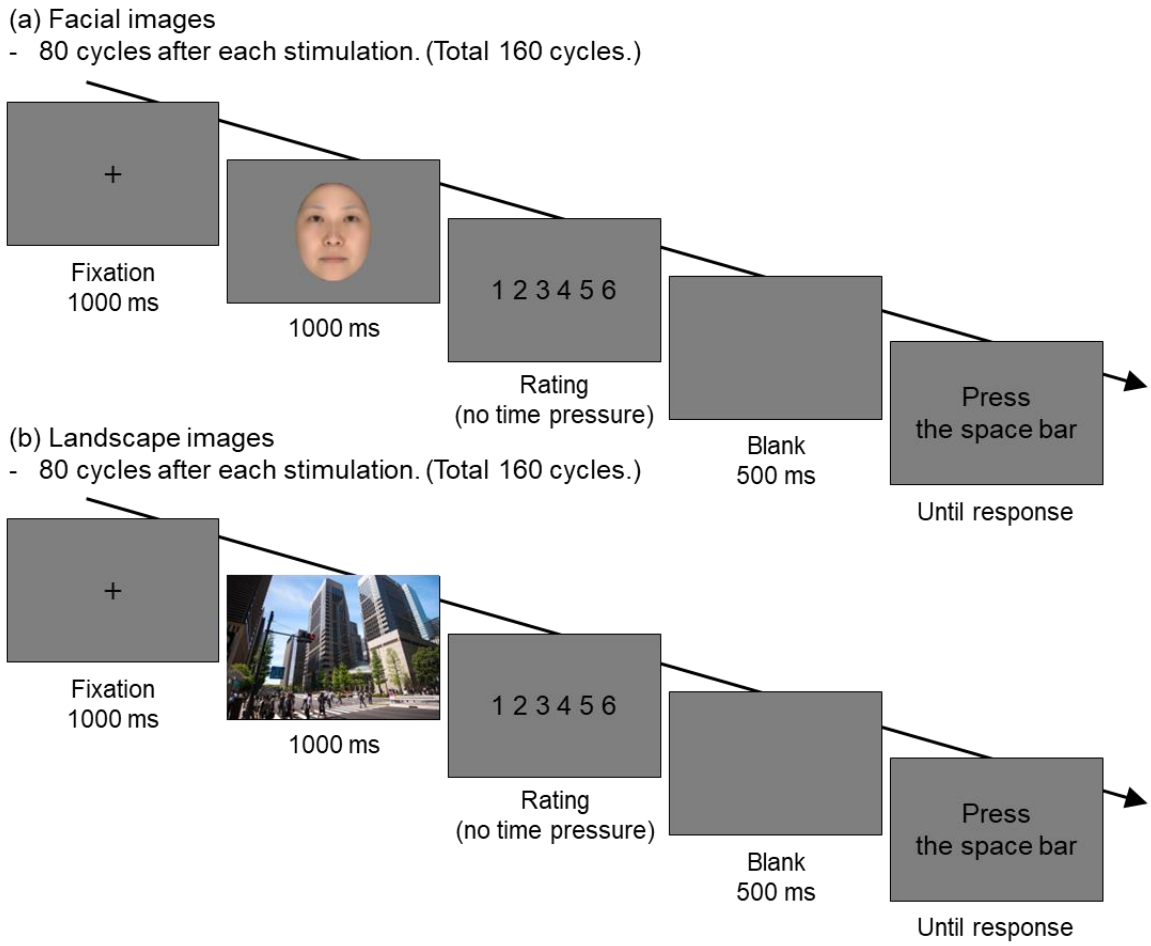

Figure 3. Flow of the experiment for visual attractiveness evaluation
(a) Facial and (b) landscape images.

Selecting Cosmetics for Tactile Impression Evaluation:

In order to mention the effect on the tactile impression of any cosmetic product, ideally all target substances should be evaluated comprehensively. However, there is a limit to the number of products used for tactile impression evaluation. Therefore, we used the evaluation results from the Check-All-That-Apply method for commercially available skincare products from POLA Chemical Industries. Based on the results, skin care products were selected, such that that the variance of the evaluation values of 17 tactile evaluation terms (e.g., moist and smooth), which are generally used to evaluate the tactile sensation of cosmetics, would be the same as the variance of the evaluation values of the selected candidate skin care products. We also added cosmetic ingredients to broaden the variance of tactile evaluation terms with narrow variance (e.g., sticky and warm). Finally, the study used 13 types of skincare products for tactile impression evaluation.

Tactile Impression Evaluation:

A single usage amount of 0.2 g of a skincare product was dropped in the center of a 10 × 10 cm^2 artificial leather (Supulare, Idemitsu Techno Fine, Japan). Each participant was instructed to touch the skincare product inside the black box using the fingerpad of their index finger and evaluate the tactile attractiveness of each skincare product using the Visual Analogue Scale. Each response was converted into a numerical value from 0 = *Not attractive* to 100 = *Very attractive* for analysis. The participants were trained to maintain a spreading speed of 3 cm/s and a pressure of 0.5 to 1.0 N, as determined by previous research [10, 11] prior to the test.

Experimental Procedure for participant:

Figure 4a presents the testing environment using each of the previously described experimental procedures. First, the participants sat on a chair with their heads immobilized and received TMS. Afterward, they evaluated visual or tactile impressions. The order of sensory impression evaluations and the stimulation patterns (iTBS or sham stimulation) was randomized and counterbalanced among them.

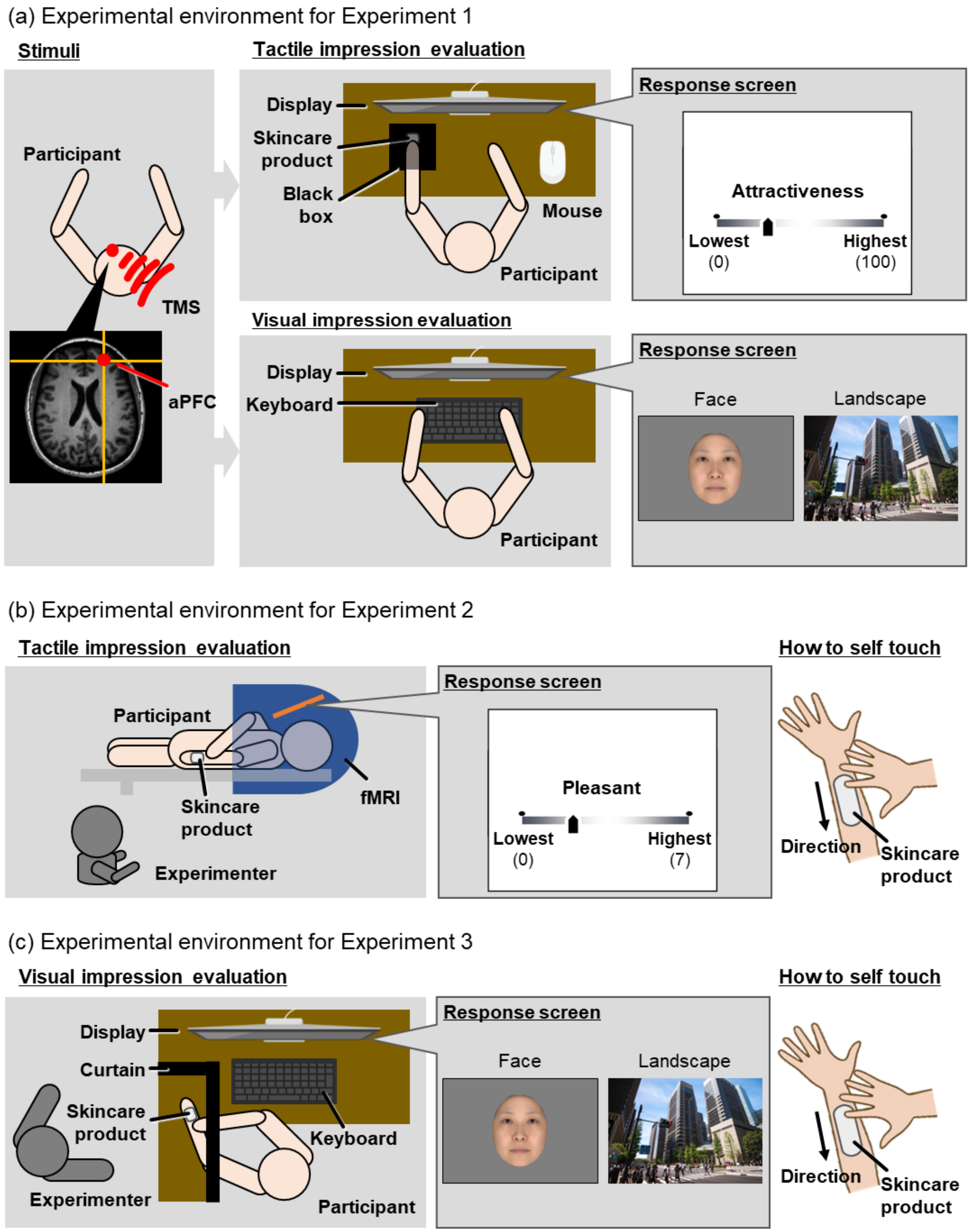

Figure 4. Experimental environment

(a) Experiment 1. (b) Experiment 2. (c) Experiment 3.

Selection of Targets for the Evaluation Analysis of Visual and Tactile Impressions:

Facial attractiveness is known to be determined in the initial stages of recognition based on a single factor, that is, facial morphology [12]. However, the aPFC is activated during the recognition of complex attractiveness impressions [13]. This notion suggests that if a face is initially recognized as unattractive based on its morphology, then attractiveness is judged without engaging the aPFC. Therefore, a number of models may not exhibit improved attractiveness ratings even with aPFC activation. To address this concern, we pre-calculated the average attractiveness rating for each facial image (average of ratings under the iTBS and sham conditions) and classified them into two groups based on these averages. We then analyzed the facial images with high (N = 40) and low (N=40) average attractiveness ratings to validate the hypothesis.

Skincare products are formulated to meet customer demands, such that their tactile attractiveness ratings are generally expected to be high. Including all skincare products in the impression evaluation may make difficult the detection of the effect of aPFC activation on the improvement of attractiveness ratings. Therefore, we pre-checked the distribution of attractiveness ratings given by each participant for each skincare product under the sham condition. Based on the results, we analyzed the ratings for skincare products that the participants considered unattractive (attractiveness rating below 50) under the sham stimulation condition as well as the ratings for skincare products judged as attractive (attractiveness rating 50 or above) to validate the hypothesis.

Method of Analysis:

We used and compared the ratings for visual and tactile impressions given by each participant under the iTBS and sham conditions. Statistical significance was tested using paired t-test or the Mann–Whitney U-test with a significance level of $p < 0.05$.

Experiment 2: Verification of the activation effect of aPFC via the tactile stimulation of skincare products using fMRI and identification of the physical properties that influence aPFC activation (Figure 1e).

Participants:

The participants were 12 Japanese women aged 20 to 59 years with an even distribution across age groups.

Selection of Skincare Products for Tactile Stimulation:

The study selected three types of skincare products as tactile stimuli. It is known that the aPFC is activated by touching pleasant objects [2]. Additionally, it is known that the sensory evaluation values for feel are positively correlated with the viscoelasticity of a solution in terms of the relationship between sensory evaluation values for the feel of skincare products and their physical property values [14]. Therefore, the current study considered that physical properties related to viscoelasticity may influence aPFC activation. Therefore, we used compliance damping (cDP), which is a viscoelastic property value measured using the SynTouch system, as an indicator of the viscoelasticity of skin care products [15].

cDP is a physical property value that indicates the speed at which a surface returns to its original shape after deformation, which is calculated using a scale ranging from 0 to 100. We pre-measured the physical properties of the 13 types of skincare products used in Experiment 1 and selected three types of skincare products with a large variance in cDP. The specific cDP values were 6.299, 8.714, and 13.95; hereafter, they will be referred to as low, medium, and high viscoelasticity, respectively.

Tactile Impression Evaluation:

A single usage amount was set to 0.2 g, and the experimenter applied the skincare product to the dorsal side of the left forearm of the participant. Under conditions in which they could not see their hands, each participant was instructed to touch the skincare product using the fingerpad of their index finger and rate the pleasantness of the tactile feel of each skincare product using a seven-point scale ranging from 1 = *Not pleasant* to 7 = *Very pleasant.*

Selection of Skincare Products and Participants for Analysis:

As previously mentioned, the aPFC is known to be activated by touching pleasant objects. Therefore, selecting skincare products that demonstrate differences in sensory evaluation values for pleasantness and selecting participants who display differences in sensory evaluation values for the selected skincare products are necessary steps. In this manner, we can accurately verify the activation effect of the aPFC through the tactile stimulation of skincare products and to identify the physical properties that influence this activation. To select the skincare products for analysis, we first confirmed the differences in sensory evaluation values for pleasantness of each skincare product. We then selected products with low and high viscoelasticity with statistically significant differences. To select the participants for the analysis, we excluded three whose sensory evaluation values for pleasantness were the same for the low- and high-viscoelasticity skincare products, as previously analyzed. Thus, the study selected nine participants for the analysis.

Experimental Procedure for participant:

To obtain fMRI data to confirm aPFC activation, we used a 3-T MAGNETOM Prisma scanner (Siemens AG, Germany) and evaluated it using the sparse sampling method [16]. The participants were trained in advance to feel the texture of the skincare products as they spread it to ensure that they fully understood the procedure prior to the experiment.

Figure 4b depicts the testing environment. The experimenter applied the skincare product to the dorsal side of the left forearm of the participant, who then spread the product (self-touch). fMRI images were between strokes of when the participants perceived the skincare products. Similar to Experiment 1, the participants were trained to maintain an application speed of 3 cm/s and a pressure between 0.5 and 1.0 N prior to the test. The order of the presentation of the skincare products was randomized and counterbalanced among the participants.

Method of Analysis:

We used Blood Oxygenation Level-Dependent (BOLD) T2*-weighted magnetic resonance signals of the conditions where each participant received tactile stimulation with low viscoelasticity and high viscoelasticity skincare products. Image processing was performed using the Statistical Parametric Mapping software [17] (SPM12, Wellcome Department of Imaging Neuroscience, United Kingdom). After normalizing the T1-weighted anatomical images of each participant, we smoothed them using a 6 mm full-width half-maximum Gaussian kernel. For the first-level analysis, we modeled the smoothed T1-weighted anatomical image of each participant for each skincare product. The second-level random effects analysis was conducted between the different skincare products. Based on brain regions identified in past fMRI studies, we set the Left-aPFC (Brodmann area 10, MNI=-23, 55, 4) as a region of interest with a sphere of 12 mm radius. We compared the differences in brain activation in the Left-aPFC under the conditions of tactile stimulation with low viscoelasticity and high viscoelasticity skincare products. Statistical significance was tested using One-way ANOVA with a significance level of $p < 0.005$, and small volume correction (SVC) was used to adjust the p-values for multiple comparisons.

Experiment 3: Verification of the effect of tactile stimulation by skincare products with different Induction Effects of aPFC activation on enhancing visual attractiveness impressions (Figure 1f).

Participants:

The study recruited 16 Japanese women aged 20 to 59 years with an even distribution across age groups.

Facial and Landscape Images for Visual Impression Evaluation:

The same images (80 images each for face and landscape) as those used in Experiment 1 were evaluated.

Visual Impression Evaluation:

The evaluation was conducted under the same conditions as those in Experiment 1.

Selection of Tactile Stimuli for Intervention:

The study used two types of skincare products for tactile stimulation, which were selected from the three skincare products used in Experiment 2, specifically the low- and high-viscoelasticity skincare products, which exhibited the largest variances in viscoelasticity.

Experimental Procedure for participant:

Figure 4c presents the testing environment. The experimenter dropped the skincare product to the dorsal side of the left forearm of the participants, who then spread the products (self-touch). Afterward, they evaluated the visual impressions of the face and landscape images. A curtain was used to ensure that the participant could not see its arm, while the skincare product was being dropped and spread. The application speed and amount of skincare product used were the same as those in Experiment 2. The order of skincare products and images presented was also randomized and counterbalanced among the participants.

Method of Analysis:

We used the impression evaluation values given by each participant during tactile stimulation using the presentation of the low- and high-viscoelasticity skincare products. We then compared the impression evaluation values between the stimulation conditions. Statistical significance was tested using the Mann–Whitney U-test with a significance level of $p < 0.05$.

Results.

Experiment 1: <u>Verification of the effect of aPFC activation by TMS on enhancing the attractive impressions of multiple senses (Figure 1d).</u>

To elucidate whether aPFC activation influences the attractiveness impressions of multiple senses, we used TMS to activate the aPFC and evaluated whether or not it could enhance the attractiveness impressions perceived through multiple senses.

In the visual evaluation of the facial images, the study observed a significant difference between the attractiveness ratings under the iTBS and sham stimulation conditions (Figure 5a). As predicted in the Materials and Methods section, no significant difference was found between the attractiveness ratings under the iTBS and sham stimulation conditions for the facial image group with low average attractiveness ratings (N = 40; data not shown).

In the visual evaluation of the landscape images, comparing the attractiveness ratings between the iTBS and sham stimulation conditions pointed to a significant difference (Figure 5b).

In the tactile evaluation of skincare products, comparing the attractiveness ratings between the iTBS and sham stimulation conditions highlights a significant difference (Figure 5c). As predicted in the Materials and Methods section, comparing the attractiveness ratings between the iTBS and sham stimulation conditions for the skincare products considered attractive (attractiveness rating of 50 or above) under the sham stimulation condition indicated that no significant difference exists (data not shown).

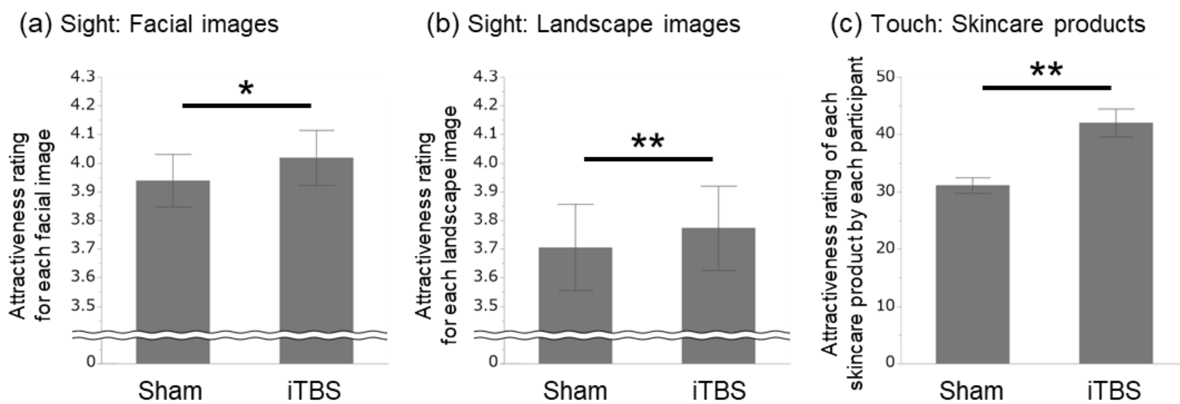

Figure 5. Effects of aPFC activation using transcranial magnetic stimulation (TMS) on attractive impressions

(a) Impression ratings of the attractiveness of the facial images by sight were significantly enhanced through the activation of the aPFC by TMS (*$p < 0.05$, N = 40, paired t-test, means ± SE). (b) Impression ratings of the attractiveness of the landscape images by sight were significantly enhanced by the activation of the aPFC through TMS. (**$p < 0.01$, N = 40, paired t-test, means ± SE). (c) Impression ratings of the attractiveness of skincare products by touch were significantly enhanced through the activation of the aPFC by TMS (**$p < 0.01$, N = 73, Mann–Whitney U-test, means ± SE).

Experiment 2: <u>Verification of the activation effect of aPFC through the tactile stimulation of skincare products using fMRI and identification of the physical properties that influence aPFC activation (Figure 1e).</u>

To elucidate whether or not tactile stimulation through touching cosmetics can induce aPFC activation and to evaluate whether or not the activation effect differs when touching cosmetics with different physical properties, we compared the differences in the brain activation of the aPFC when touching cosmetics with different physical properties using fMRI.

In the evaluation of aPFC activation, the low-viscoelasticity skincare products pointed to significant activation of the aPFC compared with the high-viscoelasticity skincare products (Figure 6).

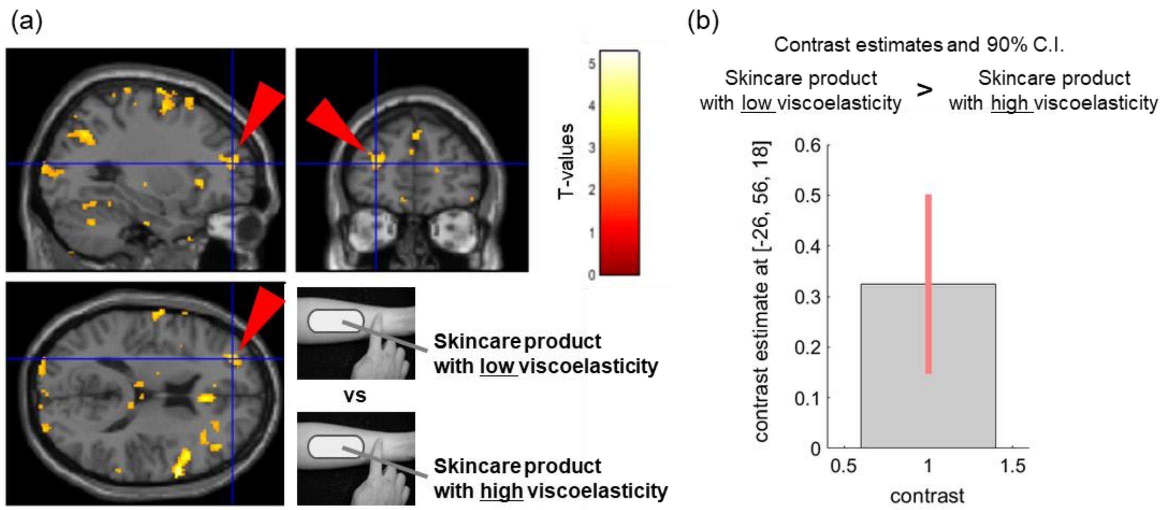

Figure 6. Verification of the activation effect of aPFC by touching skincare products and identification of the physical properties that influence aPFC activation

(a) Low-viscoelasticity skincare product activated aPFC (MNI = −28,49,15) compared with high-viscoelasticity skincare products (p < 0.005, small-volume correction (SVC) test, T = 3.443209). (b) Contrast estimates and 90% confidence intervals for aPFC at [MNI = −26, 56, 18] for contrast between low- and high-viscoelasticity skincare products (p < 0.005, N = 9, SVC test, means ± SE).

Experiment 3: <u>Verification of the effect of tactile stimulation using skincare products with different induction effects of aPFC activation on enhancing visual attractiveness impressions (Figure 1f).</u>

To elucidate whether or not touching skincare products with high aPFC-activation-induction ability can enhance the attractiveness impressions of different senses, the participants evaluated the attractiveness impressions of facial and landscape images under conditions in which they spread skincare products with high (low-viscoelasticity skincare product) or low (high-viscoelasticity skincare product) aPFC-activation-induction effects. By comparing the attractiveness ratings between conditions, we examined the impact of the tactile feel of skincare products with high levels of aPFC-activation-induction ability on visual attractiveness impressions.

In the evaluation of facial images, the comparison of the attractiveness ratings between the conditions in which the participants touched skincare products with high and low levels of aPFC-activation-induction ability indicated a significant difference (Figure 7a). Similarly, in the evaluation of the landscape images, the study found a significant difference in the attractiveness ratings between the two conditions (Figure 7b).

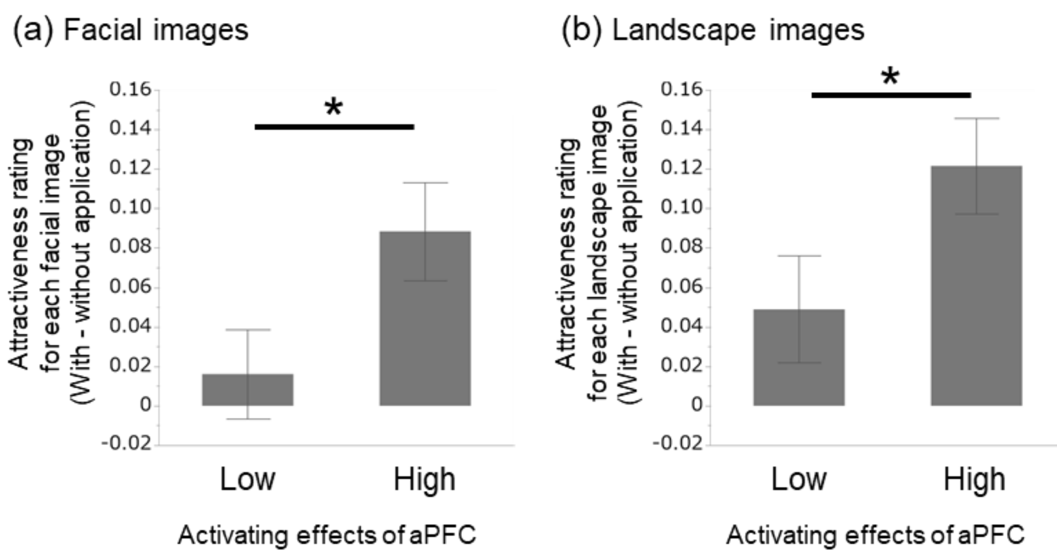

Figure 7. Effects of touching skin care products with different effects of aPFC activation on visual attractiveness.

(a) Impression ratings of the attractiveness of the facial images by sight were significantly enhanced by touching skincare products that were more effective in inducing aPFC activation (*: $p < 0.05$, N = 80, Mann–Whitney U-test, means ± SE). (b) Impression ratings of the attractiveness of the landscape images by sight were significantly enhanced by touching skincare products that were more effective in inducing aPFC activation (*$p < 0.05$, N = 80, Mann–Whitney U-test, means ± SE).

Discussion.

This study hypothesized that the aPFC is a key region that is common to the recognition of attractiveness impressions across the senses. If this hypothesis is correct, then activating the aPFC through a specific sense would enhance the attractiveness impressions of the other senses (Figure 1c). In other words, the tactile stimulation of touching cosmetics could enhance visual attractiveness impressions, which gives new sensory functions to cosmetics as tools for sensory transformation.

We have identified that the aPFC, which is a brain region involved in cognition, is activated when judging visual attractiveness and when feeling attractiveness due to inputs from other sensory organs (Figure 1ab). Therefore, we examined whether or not the activation of the aPFC, which is the opposite of a phenomenon in which aPFC is activated when attractiveness is perceived through multiple senses, influences the impression of attractiveness of multiple senses (Figure 1d). Using TMS to locally stimulate the aPFC, we examined the influence of the activation of the aPFC on the visual impression of attractiveness for model face and landscape images and tactile impressions of the attractiveness of skincare products. The results demonstrated that aPFC activation enhanced the attractiveness impressions for all evaluated targets (Figure 5). These findings suggested that the aPFC could be a key region common to the recognition of attractiveness impressions across the senses. Although the current study demonstrated that the TMS stimulation of the aPFC can enhance visual and tactile attractiveness impressions, further investigation into the other senses would strengthen the possibility of the aPFC as a key region common to the recognition of attractiveness impressions across the senses.

We then tested whether or not touching cosmetics can activate the aPFC, which is known to activate when touching something pleasant. Thus, we focused on the viscoelasticity of cosmetics, which is related to the pleasant feeling when touched. The participants were instructed to touch skincare products with different degrees of viscoelasticity, and we measured brain activation using fMRI. The results indicated that the varying degrees of viscoelasticity of skincare products lead to different activation effects on the aPFC (Figure 6). Furthermore, we revealed that touching low-viscoelasticity skincare products, which strongly activate the aPFC, can enhance the visual attractiveness impression, which is a sense that differs from touch (Figure 7). In other words, the study demonstrated that tactile stimulation from touching cosmetics could enhance visual attractiveness impressions, which provides cosmetics with a new sensory function as a tool for sensory transformation.

Cross-modality, a phenomenon in which the five senses interact with one another, has been known for a long time. In cosmetics, the tactile sensation of cosmetic products is known to cross-modally influence visual impressions and enhance evaluation [18]. By considering this concept from the brain science perspective, we found that the aPFC is involved in the brain process that occurs between the input and output senses when one sense stimulus affects the impression of another sense. In other words, we propose that the aPFC is a common and important site for the perception of attractive impressions across senses and is partially responsible for cross-modal effects. Additionally, the aPFC, which was the focus of the study, is known to activate not only when attractiveness is perceived from any sensory input but also when thinking processes are activated, such as comparisons with past experiences [13]. This process is generally called metacognition. In a society flooded with information and where things and services are easily accessible, we do not judge the attractiveness of objects based on characteristics obtained from one sense. Instead, we judge value by thinking through and comparing information obtained from various senses with accumulated experiences. Therefore, from the social perspective, focusing on metacognition, including the aPFC, is significant for enhance the thinking processes used to judge attractiveness.

This study demonstrated that touching cosmetics could make all day-to-day experiences perceived through the five senses more attractive. This concept was achieved by shifting the focus from the traditionally paired relationship between the physical properties of cosmetics and the sensory perception of such properties to the commonalities between the senses in the brain. This study focused on touch, which is one of the five senses, as the sensory stimulus to activate the aPFC. However, the key elements of user experiences with cosmetics also include scent and facial/skin features, which are perceived by smell and sight, respectively. By discovering the elements necessary to activate the aPFC through smell and sight, which lacks examination, the ways for inducing sensory transformation using cosmetics, which enhances their effectiveness as sensory transformation tools, can be increased (Figure 8a). Furthermore, enhancing the perception of hearing and taste, which lacks attention from the cosmetics industry, is possible by leveraging the results of this study (Figure 8b). This context would expand potential achievements through sensory experiences with cosmetics, which could broadening the potential of cosmetics. In other words, cosmetics would not be limited to user experiences within the closed world of cosmetics but could lead to the creation of cosmetics that enrich daily experiences, which makes cosmetics a valuable partner in living a better, well-being-oriented life.

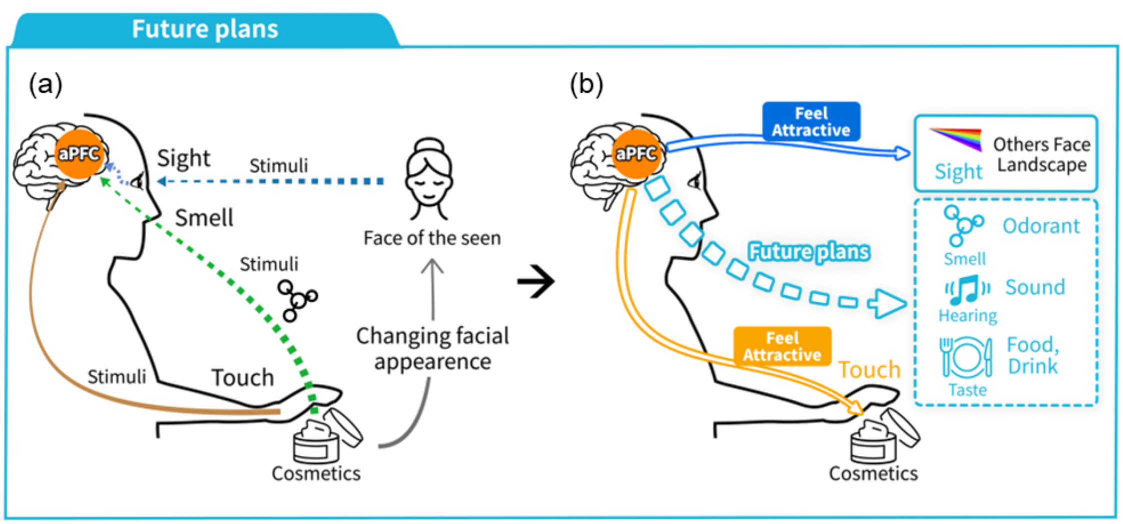

Figure 8. Schematic of future plans.

(a) Schematic of activation of the aPFC by cosmetic stimuli. (b) Schematic of sensory transformation of the five senses by aPFC activation.

Conclusion.

The improvement in attractiveness impressions perceived through sight and touch due to aPFC activation demonstrates that the aPFC is a key common area for the recognition of attractiveness across senses. Additionally, touching cosmetics with certain physical properties activated the aPFC and enhanced visual attractiveness impressions; thus, the study revealed that cosmetics can serve as sensory-transforming tools that enhance attractiveness impressions. The study expects that customers using cosmetics that activate the aPFC will find that their day-to-day experiences more attractive through the five senses.

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Conflict of Interest Statement.

NONE.

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