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Viewing a flower image provides automatic recovery effects after psychological stress

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ABSTRACT

Multiple previous studies have reported that viewing natural scenery supports recovery from psychological stress. Viewing flowers is thus predicted to provide a recovery effect similar to that of viewing natural scenery. It remains unclear, however, how effectively viewing flowers promotes recovery and how the practice affects the brain. Using psychological, physiological, and neuroscientific techniques, we investigated the process through which viewing flowers regulates emotion. We found that passive viewing of a typical flower image down-regulated negative emotions and decreased both elevated blood pressure and cortisol levels, which are two signs of stress-induced elevation, in response to an acute visual stressor (negative images). Using functional magnetic resonance imaging (fMRI), we examined brain-activation patterns relevant to emotion regulation with automatic distraction upon viewing the typical flower image. We demonstrated that activation of the right amygdala–-hippocampus region was decreased during viewing of this image in comparison to viewing a flower-mosaic or a visual fixation point after an acute visual stressor. Our results suggest that viewing a flower may induce automatic distraction from a stressor and lead to a reduction in amygdala–hippocampus activation and negative emotion, thereby downregulating physiological responses.

1. General introduction

It has been reported that viewing natural scenery supports recovery from stressful events (de Kort et al., 2006; Dravigne et al., 2008; Hartig et al., 2003; Ulrich, 1979; Ulrich, 1984; Ulrich et al., 1991). Psychological stress-related negative emotions, high blood pressure, and heart rate are efficiently decreased to baseline levels by exposure to a natural environment as compared to an urban environment (Hartig et al., 2003; Ulrich et al., 1991). Viewing flowers seems to provide a similar recovery effect as viewing natural scenery (Lee et al., 2013; Park & Mattson, 2009; Shoemaker & Relf, 1994). Flowers are given as a sympathy gift in many cultures and are often helpful for attenuating a feeling of loss (Shoemaker & Relf, 1994). Patients staying in hospital rooms that contain flowers and foliage have lower levels of anxiety and fatigue and more positive feelings than patients in hospital rooms without plants (Park & Mattson, 2009). These studies show that negative emotions can be reduced by viewing flowers. However, there is little evidence regarding whether flowers can affect the physiological responses that are induced by psychological stress. Furthermore, the manner in which the brain generates these recovery effects remains unclear. This study aimed to examine the recovery effects on stress-related cardiovascular and endocrine responses during passive viewing of a flower (studies 1 and 2), and to use functional magnetic resonance imaging (fMRI) to determine whether floral imagery altered the neural activation patterns induced by stress (study 3).

2. Study 1: Blood pressure

2.1. Introduction and hypothesis

Reduction in both negative emotion and elevated blood pressure have been reported during walking in a nature setting (Hartig et al., 2003), viewing a video of natural scenery (Ulrich et al., 1991), and hospital stays in rooms containing natural plants (Park & Mattson,

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2009). Each of these findings demonstrates that experiences with nature can induce recovery effects. Although flowers are primary elements of many natural settings, the recovery effects of viewing flowers are poorly known compared to those of viewing trees or forests. In Study 1, we investigated the impact of viewing an image of a flower on blood pressure after psychological stress. We predicted that viewing a flower image would efficiently decrease elevated blood pressure, as viewing natural scenery does (*Hypothesis 1*). In Study 1a, we compared changes in blood pressure associated with viewing a typical flower image, viewing a mosaic of fragmented flower image, and a fixation point after experiencing psychological stress. In Study 1b, we compared changes in blood pressure associated with viewing a flower image, a sky image and a chair image.

2.2. Materials and methods

2.2.1. Ethics statement

All participants (aged > 18 years) were healthy and provided written informed consent. Our protocol was approved by the Institutional Human Research Review Board of National Agriculture and Food Research Organization (NARO).

2.2.2. Flower stimulus

We classified flower forms into five types according to a prior task in which undergraduate students (27 males and 7 females; mean age, 20.3 ± 0.7 years; range, 19–22 years) were asked to draw the first flower shape that occurred to them (Fig. 1A). Type 1 was the most common choice. For this study, we selected an image of a single (daisy type) white chrysanthemum (Fig. 1B) as our flower image stimulus because of its typical shape.

2.2.3. Procedure

In Study 1a, 31 healthy participants (18 males and 13 females; mean age, 22.0 ± 4.7 years; range, 18–45 years) were recruited through our lab's website. We included the recruitment information on our website, and healthy applicants were sequentially enrolled. We performed an event-related study consisting of three viewing conditions: flower, mosaic or fixation point. Each condition involved 10 trials for a total of 30 trials. Each trial lasted 40 s, and the experiment lasted 20 min in total. In each trial, participants passively viewed an image of a white chrysanthemum (flower image; Fig. 1B), a mosaic of fragments of the flower image (flower-mosaic), or a visual fixation point for 6 s after viewing a fixation-point (2 s) followed by a high-arousal negative International Affective Picture System (IAPS) image (6 s). After the presentation of one of three stimuli (flower, mosaic, and fixation), black screen lased 26 s as recovery phase. The presentation order was counterbalanced among the three conditions across participants. As stressful IAPS images, we selected fifteen high-arousal, negative IAPS images (violence, injuries, car crashes, etc.) with a mean valence of 2.62 ± 0.3 (mean ± SD) and a mean arousal score of 5.79 ± 0.4 (Lang et al., 2008). Each negative IAPS image was presented twice during the experiment (30 trials). Participants were required to judge the unpleasantness of each IAPS image, from 1 (neutral/not unpleasant) to 4 (extremely unpleasant), using four buttons placed under their right hand while viewing each image.

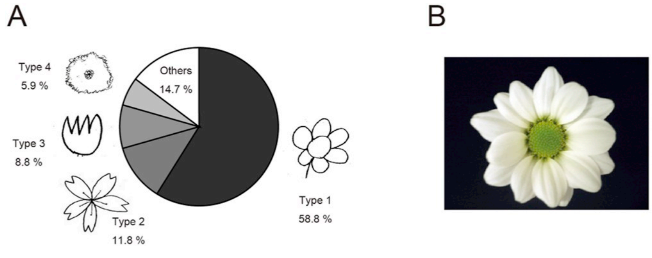

Fig. 1. Floral stimulus. **(A)** Typicality of different flower forms. **(B)** A flower image resembling the most typical flower shape (Type 1) spontaneously drawn by test participants.

For the presentation of stimuli, we used the SuperLab 4.5 software (http://www.superlab.com/). Systolic and diastolic blood pressures were continuously monitored from the left middle finger (Finometer PRO, Finapress Medical Systems) and the mean blood pressure (MBP) was calculated from these data. To ensure that acute stress was occurring and affecting blood pressure, our analyses included only selected data in which the participant had judged the preceding IAPS image as unpleasant (i.e., stressful to view). That is, we excluded trials in which the participant had judged the preceding IAPS image as neutral/pleasant from subsequent analyses. In this way, we could investigate changes in blood pressure that had previously been elevated by stress, according to our purpose. The measured MBP was transformed to a time series by interpolation and resampled at 1 Hz. The transformed data were analyzed using two-way repeated measures analysis of variance (ANOVA) with condition (flower, mosaic, and fixation) and time (40 s each) as factors. Effect sizes were calculated by dz in the post-hoc contrasts, where the mean difference was standardized by the SD of the difference between conditions for t tests (Cumming, 2012). We measured MBP for 60 s before starting the experiment and used it as the baseline value.

In Study 1b, 35 healthy participants (23 males and 12 females; mean age, 24.4 ± 7.6 years; range, 19–55 years) were involved in 30 trials consisting of the presentation of a negative IAPS image for 6 s, followed by the presentation of either a white chrysanthemum (Fig. 1B), a blue sky with clouds (nonfloral natural material; No. 5551 in IAPS), or a chair in a room (artificial material; No. 7235 in IAPS) (10 trials in each condition). The sky image represented a positive stimulus, whereas the chair image was a neutral stimulus (Lang et al., 2008). We used these stimuli to examine the relationship between positive valence and recovery effects. Fifteen high-arousal, negative IAPS images (violence, injuries, car crashes, etc.) with a mean valence of 2.71 ± 0.7 (mean ± SD) and an arousal of 5.80 ± 0.5 (Lang et al., 2008) were used as stressful images. All participants were required to judge their emotional valence twice during each trial (i.e., once while viewing the negative IAPS image and once immediately after viewing one of the three experimental stimuli) on a scale from -3 (extremely unpleasant) to 3 (extremely pleasant) ($0 = $ neutral) using seven buttons placed under their right hand. After the experiment, participants answered a questionnaire regarding the valence and arousal level of each stimulus (the flower, sky and chair images). The remaining procedures were similar to those described above with regard to Study 1a.

2.3. Results

In the analyses, we used data from the 74.2% of trials in which the IAPS images had been evaluated as unpleasant (stressful to view) in Study 1a. Mean MBP was lower when participants had viewed a flower image than when they had viewed the mosaic or the fixation point. We found a significant interaction between stimulus condition and time ($F(78, 2340) = 1.92$, $P < 0.05$) in two-way repeated ANOVA. The average reduction in MBP was significantly greater in the flower condition for 9 s than in the other conditions during the recovery phase (marked by asterisks in Fig. 2A, $P < 0.05$, values of dz and 95% CI are shown in Supplementary Table 1). In the flower condition, MBP actually decreased below the baseline level. In addition, MBP started to decrease significantly compared to the stress phase at 15th s in the flower condition ($P < 0.05$, $dz = 0.62$) as opposed to 18th s ($P < 0.05$, $dz = 0.67$) in the mosaic condition. MBP also started to decrease earlier during passive viewing of the flower than it did during passive viewing of the mosaic for 3 s.

Next, we compared subjective emotional changes and MBP recovery effects between the flower image and the sky image (nonfloral natural material) or the chair image (artificial material) (Study 1b). We used

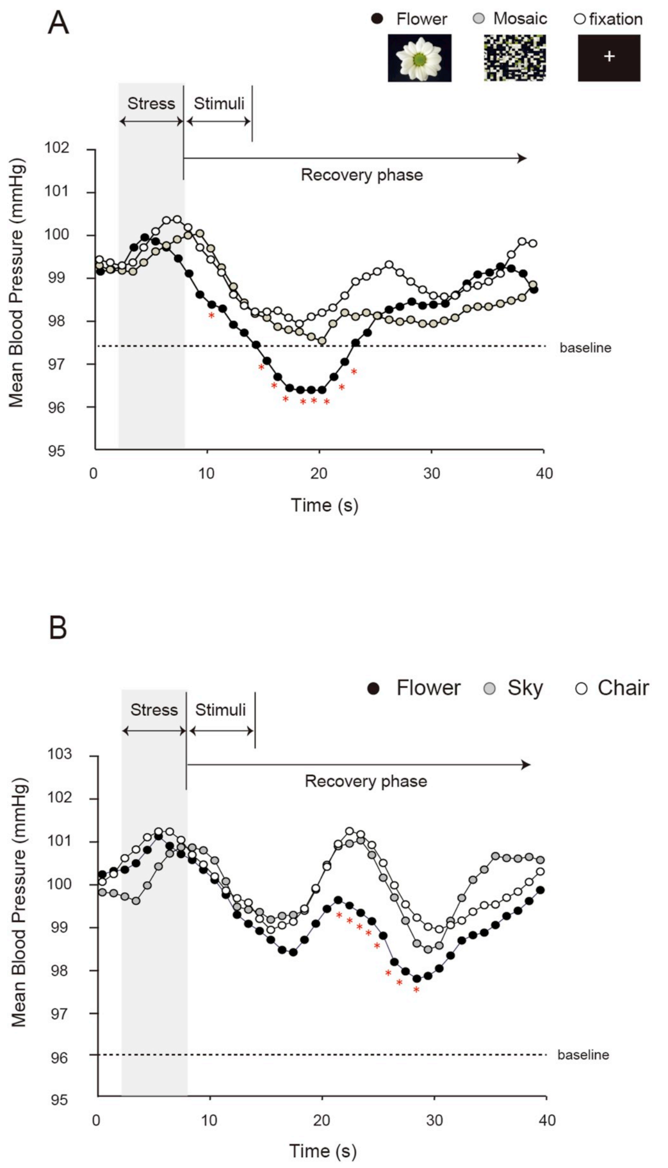

Fig. 2. Changes in mean blood pressure (MBP) during Studies 1a and 1b. (A) The effect of viewing a negative International Affective Picture System (IAPS) image for 6 s (gray color indicates the stress period) on mean blood pressure (MBP) and subsequent recovery of MBP while viewing a flower image (solid circles), a flower-mosaic (gray circles) or a fixation point (open circles), collectively termed the "stimuli", for 6 s. The MBP during 9 s of the recovery phase was significantly lower in the flower condition than in the other conditions ($P < 0.05$, marked by asterisks). The MBP started to decrease significantly earlier in the flower than in the mosaic condition for 3 s ($P < 0.05$). **(B)** The effect of viewing a negative IAPS image and subsequently viewing a flower image (solid circles), a sky image (gray circles), or a chair image (open circles) on MBP. The MBP during 8 s of the recovery phase was significantly lower in the flower condition than in the sky or chair condition ($P < 0.05$, marked by asterisks). Baseline refers to the MBP during the 60 s before starting the experiment. Standard errors are shown in Supplementary Tables 3 and 4 *$P < 0.05$.

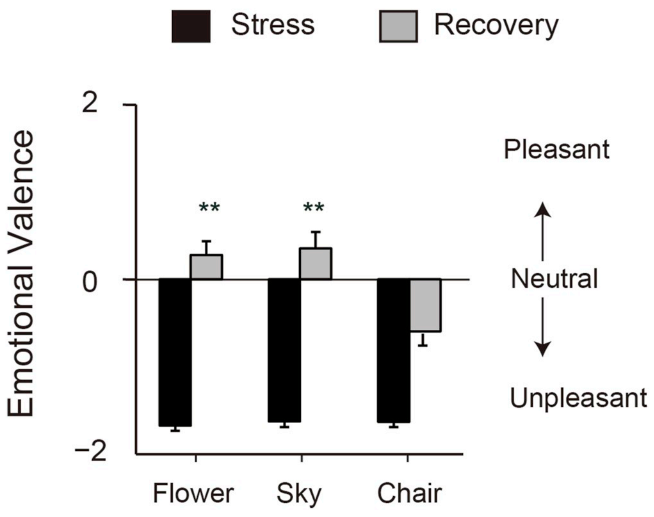

Fig. 3. Self-reported emotional valence. Mean rating scores of emotional valence during the presentation of a negative IAPS image (black bar) or after the presentation of one of three stimuli: flower, sky, or chair (gray bar). The changes in emotional valence were significantly larger in the flower and sky conditions than in the chair condition ($P < 0.01$). **$P < 0.01$.

Table 1
Mean values (± standard deviation) of valence and arousal from − 3 (negative or low arousal) to + 3 (positive or high arousal) for each stimulus.

	Flower	Sky	Chair
Valence	1.40 (0.99)	2.17 (0.84)	0.06 (1.04)
Arousal	− 0.83 (1.08)	0.80 (1.43)	− 1.06 (1.09)

data from the 81.9% of trials in which IAPS images had been evaluated as unpleasant for our data analyses. Mean MBP was maintained at a low value only in the flower condition. Two-way repeated ANOVA revealed a significant interaction between stimulus condition and time (F (78, 2652) = 1.94, $P < 0.05$). For 8 s, the MBP was significantly lower in the flower condition than it was in the sky or chair condition (marked by asterisks in Fig. 2B, $P < 0.05$, values of dz and 95% CI are shown in Supplementary Table 2). The interaction was also significant (F (2, 68) = 25.34, $P < 0.01$) in the analyses of self-reported emotional valence; however, the presentation of either the flower image or the sky image significantly diverted the subjects' emotions from negative to positive compared to presentation of the chair image (gray bar in Fig. 3, $P < 0.01$, flower; dz = 0.89, 95% CI = 0.54, 1.18, mosaic; dz = 1.06, 95% CI = 0.47, 1.02) during the recovery phase. These results suggest that the flower and sky images equally changed the subjective negative emotions aroused by the negative IAPS images, whereas only the flower stimulus significantly decreased MBP. The mean valence value of each stimulus revealed that the positive valence of the sky image was significantly higher than that of the flower image ($P < 0.05$, dz = 0.72, 95% CI = 0.42, 1.13, Table 1) or the chair image ($P < 0.05$, dz = 1.51, 95% CI = 1.58, 2.47, Table 1), and that the flower image was evaluated as significantly more positive than the chair image ($P < 0.05$, dz = 0.88, 95% CI = 0.79, 1.73 Table 1). In terms of arousal value, the sky image elicited a significantly higher arousal than the flower image ($P < 0.05$, dz = 0.90, 95% CI = 0.98, 2.11, Table 1) or the chair image did ($P < 0.05$, dz = 1.05, 95% CI = 1.21, 2.33, Table 1).

2.4. Discussion

The results of Study 1a and lb jointly revealed that viewing an image of a typically-shaped flower decreased elevated blood pressure to a greater degree than viewing other stimuli such as a flower-mosaic or a chair image did; this supports our *Hypothesis 1*. Our results suggest that viewing a flower image provides psychological and physiological recovery effects after stress. This result is consistent with the results of previous studies regarding natural scenery (Hartig et al., 2003; Ulrich et al., 1991) or natural flowers and foliage (Park & Mattson, 2009).

Kaplan (1995) proposed a theoretical background to explain the restorative effects of the natural environment. In his theory, natural settings are qualified as soft fascination, that readily hold human attention (Kaplan, 1995; Kaplan & Talbot, 1987). Natural materials such as clouds, insects, leaves or flowers catch participants' attention with minimal effort (Kaplan, 1995), and give viewers the opportunity to free themselves from stressful thoughts and memories (Bratman et al., 2015; Ulrich et al., 1991). The process of shifting one's attention from stressor to nature seems to be similar to the cognitive process of distraction. In the strategy of distraction, for example, participants were instructed to pay attention to something positive or neutral when experiencing stressful events so as not to increase negative emotions (Kalisch et al., 2006; McRae et al., 2010). Distraction has been well investigated in various research fields of human health including psychological, psychosomatic and neuroscientific areas (Gerin et al., 2006; Kalisch et al., 2006; Larsen et al., 2009; McRae et al., 2010). Successful distraction from a stressor induces a reduction in stress-associated high-blood pressure (Gerin, 2006; Glynn et al., 2002; Larsen et al., 2009). Our results imply that an image of a flower can induce distraction from stressful images, allowing reductions in negative emotions and stress-associated sympathetic activation.

However, not every natural material may yield an equivalent physiological recovery effect. Sky images did not decrease MBP although flower images did. Although the positive sky image did successfully decrease unpleasant feelings, it might actually have increased MBP because of its relatively high arousal value (Gomez & Danuser, 2010). A relatively low arousal value as well as a positive valence might be necessary requirements for a stimulus to have a physiological recovery effect. We observed different patterns in MBP fluctuations between Studies 1a and 1b (Fig. 2); specifically, MBP was higher during the middle recovery phase in Study 1b. A second emotional evaluation after viewing both stimuli was performed only in Study 1b and not in 1a; this situation may have affected the sympathetic nervous system and increased MBP.

3. Study 2: Salivary cortisol

3.1. Introduction and hypothesis

Salivary cortisol has often been used in previous studies assessing the effects of stress and coping on the endocrine system (e.g., Duncko et al., 2009; McEwen, 2008). To date, however, it is not well known how viewing a flower after psychological stress affects cortisol levels. We compared salivary cortisol levels after viewing a typical flower image with those after viewing a mosaic image of flower fragments after viewing stressful images. We predicted that viewing a flower would decrease cortisol levels to a greater degree than viewing mosaic fragments would (*Hypothesis 2*), because we had found in Study 1 that viewing a flower image significantly reduced elevated blood pressure.

3.2. Materials and methods

3.2.1. Ethics statement

All participants (aged > 18 years) were healthy and provided written informed consent. Our protocol was approved by the Institutional Human Research Review Board of National Agriculture and Food Research Organization (NARO).

3.2.2. Flower stimulus and procedure

We used an image of a typically-shaped flower (Fig. 1B) as the floral stimulus. We recruited 32 male participants (mean age, 21.6 ± 2.0 years; range, 18–27 years) via our lab website. Female participants were excluded from the cortisol study because the menstrual cycle affects stress hormone reactivity (Kirschbaum et al., 1999). All participants were tested in the afternoon (2:00 p.m. to 4:00 p.m.) to minimize the contribution of diurnal variations in cortisol release (e.g., Duncko et al., 2009). Each participant was randomly assigned to one of the two groups. In one group, participants viewed a series of negative IAPS images followed by the flower image as the first condition (IAPS-flower condition). After resting for 40 min, they viewed another series of negative IAPS followed by the flower-mosaic image as the second condition (IAPS-mosaic condition). Members of the second group participated in the two conditions in reverse order (IAPS-mosaic followed by IAPS-flower). We prepared 16 high-arousal, negative IAPS images (violence, injuries, car crashes, etc.) with a mean valence of 2.55 ± 0.6 (mean ± SD) and an arousal score of 5.83 ± 0.4, and divided them into two equivalent sets (Lang et al., 2008). Of the two sets, one was used in each condition (IAPS-flower or IAPS-mosaic). We counterbalanced the image set used for each condition across participants.

In each condition, after the presentation of a black screen for 4 min, participants passively viewed eight IAPS images (each was presented for 12 s with an ISI of 18 s), then viewed the flower image or the flower-mosaic for 8 min. After the presentation, participants were asked to keep sitting on the seat and rest. There is a time lag between cortisol response and stress (Bozovic et al., 2013; Kirschbaum & Hellhammer, 2000). In response to stress, blood level of cortisol gradually increases and shows peak in 10–30 min after the stressful event. The transfer of cortisol from blood to saliva takes place within no more than 2–3 min (Bozovic et al., 2013). Then, in the present study, saliva samples were obtained 17–20 min and 35–38 min after the beginning of the image presentation in each condition. The first sample was used to measure cortisol under the stress condition, whereas the second sample was used to measure cortisol during recovery. Salivary cortisol levels were determined using enzyme-linked immunosorbent assay (EIA kit 1–3002, Salimetrics). The cortisol data were analyzed using two-way repeated measures ANOVA, including condition (IAPS-flower and IAPS-mosaic) and phase (stress and recovery). Effects sizes were calculated by *dz* in the post-hoc contrasts (Cumming, 2012).

3.3. Results and discussion

We found a significant interaction between stimulus and time (F (1, 31) = 4.28, $P < 0.05$) in two-way repeated ANOVA. The cortisol levels in response to negative IAPS images did not differ between the flower and the mosaic conditions (black bar in Fig. 4). The subsequent presentation of the flower image, but not the mosaic, significantly decreased salivary cortisol levels in the recovery phase (gray bar in Fig. 4, $P < 0.01$, $dz = 0.78$, 95% CI = 0.008, 0.020). The cortisol results suggest that viewing a flower image has an impact on the endocrine system, reducing saliva cortisol levels after they were elevated by psychological stress. *Hypothesis 2* was thus also supported.

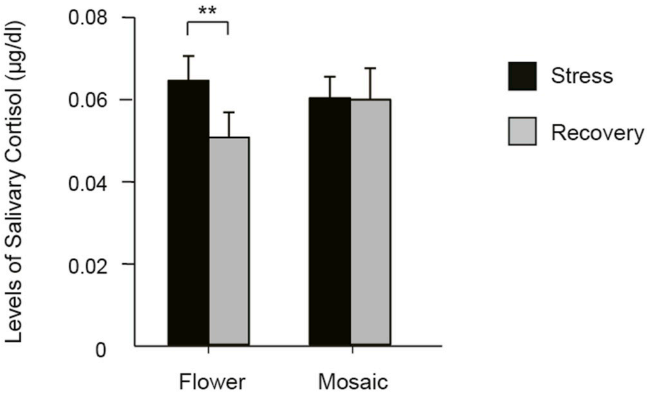

Fig. 4. Changes in mean salivary cortisol levels. Salivary cortisol levels after the presentation of a series of negative IAPS images (stress phase; black bar) and after the subsequent presentation of a flower image or mosaic (recovery phase; gray bar). Only in the flower condition, salivary cortisol levels significantly decreased in the recovery phase ($P < 0.01$). **$P < 0.01$.

4. Study 3: fMRI

4.1. Introduction and hypothesis

The neural basis underlying the downregulation of negative emotions has been investigated using multiple strategies including reappraisal, distraction, detachment, and others (Braunstein et al., 2017; Butler & James, 2010; Dörfel et al., 2014; Kalisch et al., 2005, 2006; Kanske et al., 2010; Lévesque et al., 2003; McRace et al., 2010; Schönfelder et al., 2014; Sripada et al., 2013). The recovery effect of viewing flowers seems to involve a cognitive process similar to that of distraction, as natural materials tend to catch participants' attention with minimal difficulty (Kaplan, 1995). The results of Study 1 and 2 also suggested that a flower image can act as a distractor, allowing reductions in negative emotions and stress-associated sympathetic activation. It is important to note that, in both previous studies on the effects of a natural environment and the present study, participants were simply presented with a natural movie, picture or real plants after psychological stress (de Kort et al., 2006; Dravigne et al., 2008; Hartig et al., 2003; Stone, 2003; Ulrich, 1979; Ulrich, 1984; Ulrich et al., 1991), and there was no attempt to alter either emotion or cognition. This suggests that the distraction process might proceed automatically.

The neural basis of distraction has been extensively investigated (Kalisch et al., 2006; Kanske et al., 2010; McRace et al., 2010). However, previous fMRI studies have employed a controlled distraction strategy, i.e., participants were instructed to try to keep a series of letters in their minds during the presentation of negative emotional stimuli so as not to increase negative emotions (McRace et al., 2010). The details of how the brain regulates emotion with automatic distraction remain unclear.

Decreased activation in the limbic regions, especially the amygdala, has often been reported during the attenuation of negative emotions (Dörfel et al., 2014; Kanske et al., 2010; Lévesque et al., 2003; McRace et al., 2010). Dörfel et al. (2014) have investigated brain-activation patterns during the downregulation of negative emotions using multiple strategies and reported decreased amygdala activation as a result of distraction as well as detachment or expressive suppression. We predicted that amygdala activation would be decreased if negative emotions were successfully attenuated during passive viewing of a flower image (*Hypothesis 3*). In contrast, the bilateral prefrontal and parietal regions are reported to be activated during controlled distraction (Dörfel et al., 2014; Kalisch et al., 2006; Kanske et al., 2010; McRace et al., 2010). The increasingly activated regions tend to play a smaller role during automatic and/or implicit emotion regulation than during controlled ones (Braunstein et al., 2017). We predicted that the present automatic distraction phenomenon would activate the prefrontal and/or parietal regions to a lesser degree compared with previous explicit–controlled distraction studies (Dörfel et al., 2014; Kalisch et al., 2006; McRace et al., 2010).

4.2. Materials and methods

4.2.1. Ethics statement

All participants (aged > 20 years) were healthy and provided written informed consent. Our protocol was approved by the Institutional Human Research Review Board and the MRI Research Review Board of Advanced Industrial Science and Technology (AIST).

4.2.2. Flower stimulus and procedure

We used an image of a typically-shaped flower (Fig. 1B) as the floral stimulus. We recruited 17 right-handed (score > 80 on the Edinburgh Handedness Inventory) (Oldfield, 1971) healthy participants (10 males and 7 females; mean age, 25.5 ± 1.5 years; range, 21–41 years) via our lab website. All participants were native Japanese speakers who had no history of neurological or psychiatric disorders.

The experiment consisted of 31 blocks, including five flower image blocks, five flower-mosaic blocks, five fixation point blocks, and 16 resting baseline blocks that were placed between three types of experimental blocks (Supplementary Fig. 1A). Participants were instructed simply to view the consecutive images and allow their natural responses (feelings/emotions) to occur. Thirty high-arousal, negative IAPS images with a mean valence of 2.84 ± 0.9 (mean ± SD) and a mean arousal score of 5.81 ± 0.8 were divided into three sets (Lang et al., 2008). Of the three sets, one was used for each condition. The presentation order was counterbalanced among the three conditions across participants. Participants viewed 4-s sequences of negative IAPS images interspersed with 3-s presentations of the flower image, the mosaic image, or a fixation point (Supplementary Fig. 1B). In the final phase of the block trial, participants were asked to rate their current emotional valence from 1 (neutral/not unpleasant) to 5 (extremely unpleasant). During the resting baseline blocks, a fixation point was presented for 20 s. All fMRI data were acquired with a 3-T GE scanner. The participants were positioned in the scanner with their heads immobilized with support cushions and a neck support. Scanner noise was decreased with earplugs. All stimuli were presented through a projector and were back-projected onto a screen that was placed above the participants' feet. Participants viewed the stimuli through a mirror attached to the GE quad head coil of the MRI scanner. The timing of stimulus presentation was controlled by combining the absolute time with the TTL pulse triggered from the MRI scanner. For stimulus presentation, we used SuperLab 4.5 software (http://www.superlab.com/). The responses from each participant were recorded using an MRI Compatible Key Pad System (Resonance Technology: http://www.mrivideo.com).

Before the fMRI scanning, a structural localizer (spoiled gradient) was acquired in the sagittal plane with the following parameters: repetition time (TR) = 68 ms, echo time (TE) = 1.6 ms, field of view (FOV) = 24 × 24 cm^2, matrix size = 256 × 128, flip angle = 30° and slice thickness/gap = 7/3 mm. For fMRI scans, gradient-echo echo-planar imaging (EPI) was performed with the following parameters: TR = 2000 ms, TE = 30.0 ms, FOV = 20 × 20 cm^2, matrix size = 64 × 64, flip angle = 75°, slice thickness/gap = 4/1 mm and voxel size = 3.125 × 3.125 × 5 mm. Twenty-seven horizontal slices were obtained and three sets of 310 sequential volumes were collected in each run. High-resolution T2-weighted anatomical images were collected (TR = 24 ms, TE = 5 ms, FOV = 20 × 20 cm^2, matrix size = 256 × 192, flip angle = 90° and voxel size = 0.78 × 1.04 × 5 mm) at the same slice positions used in the EPI scans.

The preprocessing and statistical analyses of all the functional images were performed with SPM5 software (Wellcome Department of Cognitive Neurology, London, UK). During preprocessing, the time series of the EPI volumes was first corrected for differences in slice acquisition time and realigned for motion correction. Second, these realigned images were coregistered with the T2 anatomical images from each participant. Third, a parameter file for spatial normalization with the Montreal Neurological Institute (MNI) brain template was constructed from the individual T2 anatomical images with a standard SPM T2 template. All EPI volumes coregistered with anatomical images were spatially normalized into MNI space with the parameter file and resliced into a resolution of 2 × 2 × 2 mm voxels. All spatially normalized EPI data were then spatially smoothed with a Gaussian kernel of Full-Width Half-Maximum = 8 mm.

4.2.3. fMRI data analysis

Statistical analyses of the fMRI data were performed first at the subject level and then at the group level. At the subject level, fixed-effect analyses were performed in individual participants. A specific effect was estimated for each condition (flower image, flower-mosaic, and fixation point) in the form of t-contrast against zero. For the group-level random effect analysis, we used contrast images from the subject-level fixed-effect analyses and generated a model of repeated measures whole-brain ANOVA with the factor of condition (flower, flower-mosaic, and fixation point) in the SPM5 full factorial option. At this level of analysis, we applied two patterns of statistical analysis. First, to identify the brain regions that showed decreased brain activation after viewing the flower image compared to those that showed a decrease in brain activation after viewing the mosaic and fixation point images, the main effect of condition ($F > 8.00$) was inclusively masked with the contrasts of flower-mosaic vs. flower and fixation point vs. flower. Second, to obtain exploratory data about the brain regions that were specifically activated during emotional regulation with the flower image, the main effect of condition ($F > 8.00$) was inclusively masked with the contrasts of flower image vs. flower-mosaic and flower image vs. fixation point. The ANOVA analysis was performed at an intensity threshold of $P < 0.001$, uncorrected, with a minimum cluster size of 11 voxels which were calculated through Monte Carlo simulations (https://www2.bc.edu/sd-slotnick/scripts.htm) to define the individual cluster extent threshold for multiple comparisons (Abel et al., 2014; Slotnick et al., 2006). In the current study, a Monte Carlo correction with 1000 simulations identified and 11 resampled voxels was necessary to obtain results that were corrected for multiple comparisons at $P < 0.05$.

To identify the precise role of each activated region that was detected through whole-brain subtraction analyses, we compared the parameter estimates during each block of condition with MarsBar software (http://marsbar.sourceforge.net/) in each region. The mean parameter estimates in each cluster of the regions of interest (ROIs) were compared using one-way ANOVA with condition as the factor. We predicted that the amygdala activation would be detected as regions that are deactivated by the flower image in the whole-brain ANOVA analyses, whereas limited areas of the frontal and/or parietal regions might be detected as regions activated during the regulation of emotion upon viewing a flower.

A hypothesis-driven ROI approach was also used to reveal downregulation in the activation of the bilateral amygdala. We created 5-mm spherical ROIs in the amygdala that were centered around Dörfel and colleagues' (2014) coordinates (−30, 0, −18 and 24, −3, −18). 8-mm spherical ROIs that were centered around alternate coordinates (−21, −6, −15 and 33, −9, −15) were also created around the amygdala and surrounding region (amygdala–hippocampus; Dörfel et al., 2014). These regions are deactivated by multiple strategies that regulate emotion, including distraction, detachment, and expressive suppression (Dörfel et al., 2014). We compared the parameter estimates using MarsBar (http://marsbar.sourceforge.net/) during each block of conditions in each ROI with one-way ANOVA or effect size *dz* (Cumming, 2012).

We determined the location of each cluster according to probabilistic cytoarchitectonic maps in the SPM Anatomy Toolbox (http://www.fz-juelich.de/inm/inm1/DE/Forschung/_docs/SPMAnatomyToolbox/SPMAnatomyToolbox_node.html).

4.3. Results

We examined the brain-activation patterns associated with the automatic emotion regulation induced by viewing the flower image. The main effect of the stimulus on mean unpleasantness ratings was significant ($F(2, 32) = 5.33$, $P < 0.05$), and the unpleasantness scores were significantly lower in the flower condition than in the mosaic ($P < 0.05$, $dz = 0.92$, 95% CI = 0.32, 1.01, Fig. 5) and fixation conditions ($P < 0.05$, $dz = 0.53$, 95% CI = 0.04, 0.81, Fig. 5), which suggests that only the flower image decreased the subjective unpleasant emotions that were aroused by the negative IAPS images. fMRI results demonstrated that the activation in the region of the right amygdala–hippocampus (x, y, z coordinates of +26, −10, −20, respectively; Fig. 6, left, Table 2) decreased more during the viewing of the flower image than during either of the other two conditions. The decrease in activation (parameter estimates) was significantly larger in the flower condition than in the mosaic ($P < 0.05$, $dz = 0.86$, 95% CI = 0.12, 0.43, Fig. 6, right) or fixation conditions ($P < 0.05$, $dz = 0.72$, 95% CI = 0.09, 0.45, Fig. 6, right). Activation in and around the bilateral insular cortex and that in the right caudate were also decreased while viewing the flower image (Table 2). In hypothesis-driven ROI analyses, we also found deactivation in the bilateral amygdala regions (Fig. 7). Activation of the left amygdala (−30, 0, −18) was significantly decreased in the flower condition compared to the mosaic ($P < 0.05$, $dz = 0.67$, 95% CI = 0.06, 0.36, Fig. 7A) and fixation conditions ($P < 0.05$, $dz = 0.51$, 95% CI = 0.02, 0.40, Fig. 7A). In the left amygdala to hippocampus region, brain activation was decreased during the flower condition compared to the fixation condition (−21, −6, −15; $P < 0.05$, $dz = 0.52$, 95% CI = 0.02, 0.39, Fig. 7C). Activation in the right amygdala to hippocampus region (+33, −9, −15) was also decreased in the flower condition compared to the mosaic condition ($P < 0.05$, $dz = 0.66$, 95% CI = 0.03, 0.21, Fig. 7D) and tended to be lower during the flower condition than during the fixation condition ($P = 0.0599$, $dz = 0.47$, 95% CI = 0.00, 0.17, Fig. 7D). No brain regions were significantly activated during the flower condition compared to the mosaic and fixation conditions.

Fig. 5. Mean subjective unpleasantness rating scores. Mean unpleasantness rating scores in the three conditions (flower, mosaic, and fixation point) during the fMRI experiment. Mean unpleasantness was significantly lower in the flower condition than in the other conditions ($P < 0.05$). *$P < 0.05$.

4.4. Discussion

The neural activation patterns revealed deactivation in the amygdala-hippocampus region during automatic decreases in negative emotions induced by the flower image, confirming our prediction (*Hypothesis 3*). The present results are consistent with the results of previous studies suggesting that the amygdala is involved in emotion generation (Ochsner et al., 2009) and that decreased amygdala activation is key in successfully attenuating negative emotions (Dörfel et al., 2014; Kanske et al., 2010; Lévesque et al., 2003; McRace et al., 2010; Sripada et al., 2013). A stronger decrease in amygdala activation has been reported during distraction than during other strategies (Dörfel et al., 2014; Kanske et al., 2010). In addition, the hippocampus is involved in emotion processing (Habel et al., 2005; Reinders et al., 2006) and emotion regulation by suppressing negative memories (Butler & James, 2010). Flower images like ours might prevent the recall of stressful images and contribute to a decrease in unpleasant feelings. The results of both whole brain subtraction and ROI analyses indicated downregulation in brain activation in the right amygdala and surrounding region. Right amygdala activation is linked to autonomic arousal, whereas left amygdala activation is more closely associated with cognitive processing and recognition of emotional stimuli (Skuse et al., 2005). Flower images may have a higher impact on right side amygdala–hippocampus activations than on left side activations and

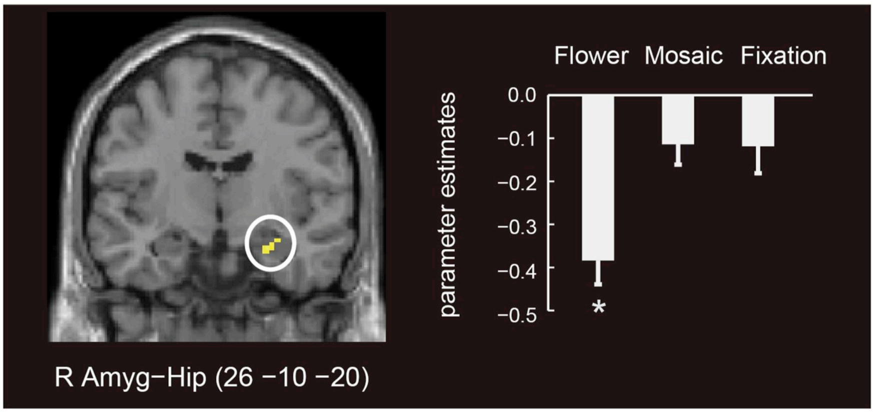

Fig. 6. Brain regions showing decreased activation during automatic emotional regulation induced by a flower image. Left: Brain regions that were significantly activated during the mosaic and fixation conditions relative to the flower condition. Right hippocampus–amygdala (R Hipp–Amyg; located within the white circle at 26, −10, −20). Right: The decrease in the mean parameter estimates in the R Hipp–Amyg was larger in the flower condition than in the mosaic and fixation conditions ($P < 0.05$). *$P < 0.05$.

Table 2

Regions of the brain with significantly decreased activation during the flower-image condition relative to the flower-mosaic and fixation-point conditions. Activation was thresholded at Monte Carlo-corrected $P < 0.05$ with at least 11 voxels. Cytoarchitectonic areas were determined on the basis of the probabilistic cytoarchitectonic maps in the Anatomy Toolbox.

	Anatomical Location	MNI Coordinates			*F* value	Voxel size
		x	y	z		
Right	Insula	36	−22	6	8.91	12
	Amygdala/Hippocampus	26	−10	−20	9.26	12
	Caudate	18	26	4	9.55	13
Left	Rolandic operculum/Insula	−44	−2	0	12.04	107
	Rolandic operculum	−36	−8	16	9.61	27
	Transverse temporal gyrus/ Insula	−38	−22	8	12.18	23

might have more influence on automatically generated emotions than on intentionally generated ones.

The bilateral insular cortex was also detected as a region with decreased activation during the flower condition, which is consistent with the results of previous studies in which the insula was deactivated by the downregulation of emotions (Kanske et al., 2010; McRace et al., 2010; Urry et al., 2006). Similar to the amygdala–hippocampal region, decreased activation in the bilateral insular cortex might contribute to the stress-coping effects of flowers.

Although we predicted increased activation in the prefrontal and parietal areas, our subtraction analysis did not detect any significant activation in the frontoparietal cortical area in the flower condition compared to the mosaic and fixation conditions. The automatic regulation of emotion may require less brain activation than explicit–controlled strategies. In a previous study using an attentional task, activity in the associated brain regions was less in the involuntary condition than in the voluntary condition (Esterman et al., 2008). Bottom–up emotion processing activates limited areas of the cerebral cortices compared to top–down emotion processing (Ochsner et al., 2009). In general, automatic cognitive activities seem to induce less activation than controlled ones.

5. General discussion

Two major findings emerged from the current research study. First, the passive viewing of a typical flower image automatically decreased negative emotion and accelerated the recovery of cardiovascular and endocrine stress responses. Second, activation in the amygdala–hippocampus region was decreased during passive viewing of a flower image after psychological stress. Decreased activation in the amygdala–-hippocampus region might induce an inhibition of sympathetic nervous activity. To the best of our knowledge, this is the first study to demonstrate the psychological, physiological, and neural benefits of viewing a typical flower image after psychological stress. Viewing flowers, therefore, may offer recovery effects comparable to those of viewing forests.

5.1. Recovery effects provided by passive viewing of a flower

Studies 1 and 2 provided evidence that the passive viewing of a typical flower image facilitates recovery from psychological stress in terms of both psychological and physiological effects. Our results are consistent with the results of previous studies in environmental psychology (de Kort et al., 2006; Hartig et al., 2003; Lee et al., 2013; Park & Mattson, 2009; Shoemaker & Relf, 1994; Ulrich et al., 1991), and psychosomatic medicine (Gerin et al., 2006; Glynn et al., 2002; Larsen et al., 2009). These results suggest that viewing a flower image is useful to decrease negative emotions and acute physiological responses induced by psychologically stressful events. Study 3 provided details on the neural changes underlying flower-associated recovery effects, especially with regard to the decreased activation in the amygdala–-hippocampus region. Deactivation in the right amygdala region in particular might contribute to the automatic downregulation of negative emotion (Skuse et al., 2005).

Automatic distraction induced by the passive viewing of flowers appears to be a simpler and more convenient strategy for emotion regulation compared to controlled strategies, which require cognitive control including inhibition, maintenance, or manipulation of information in the working memory (Butler & James, 2010; Dörfel et al., 2014; Kalisch et al., 2005, 2006; Kanske et al., 2010; Lévesque et al., 2003; Mauss et al., 2007; McRace et al., 2010; Schönfelder et al., 2014; Sripada et al., 2013; Williams et al., 2009). The simplicity of this strategy may explain why the custom of sending flowers to persons under stress became popular and is practiced in many countries.

5.2. Contribution to human health

In the present study, viewing a flower (image) served as a useful distractor after psychological stress. Relationships among the natural environment, distraction and human health have been investigated previously. Bratman et al. (2015) reported that natural settings are effective distractors that enable viewers to maintain the shift of attention away from rumination. Rumination is a maladaptive pattern of self-referential thoughts that has been linked to the risk for psychiatric disease (Bratman et al., 2015; Nolen-Hoeksema et al., 2008) and cardiovascular disease (Gerin et al., 2006; Larsen et al., 2009). If viewing flowers for an adequate amount of time successfully reduces the incidence of flashbacks to harmful memories or rumination, this practice might help alleviate a troubled mind or reduce cardiovascular load in people under psychological stress. The medical impact of viewing

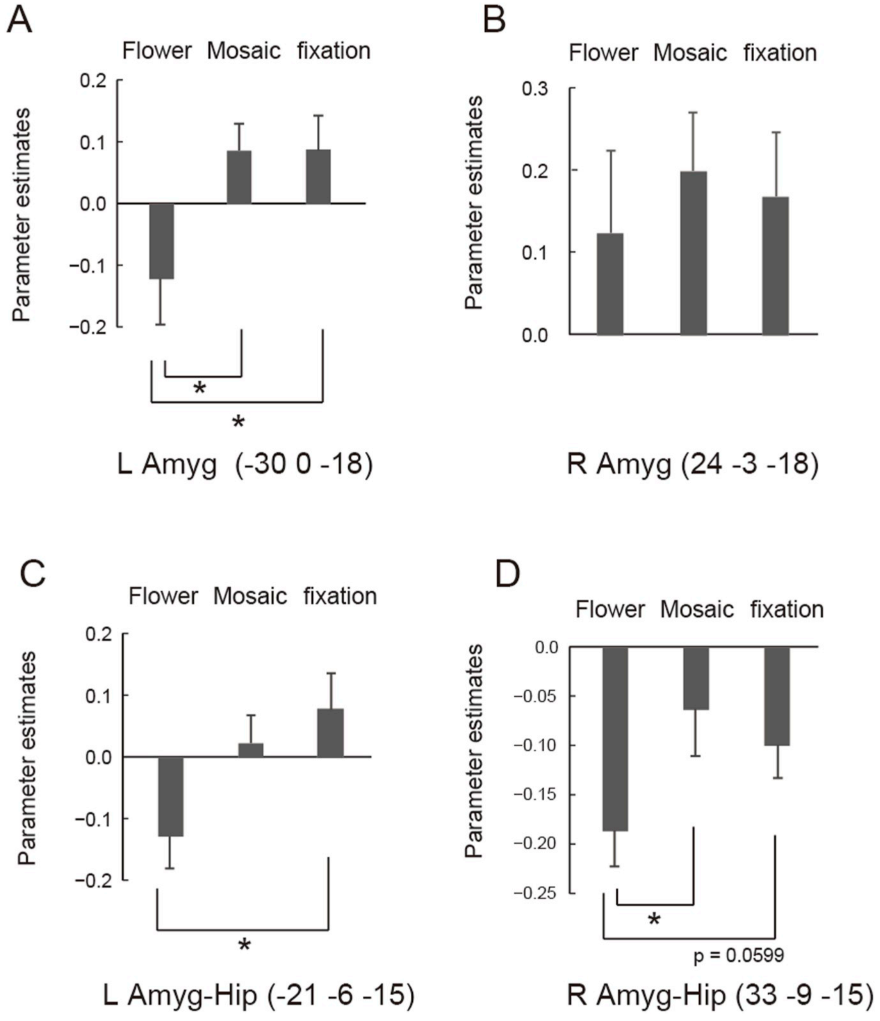

Fig. 7. Brain activation in the amygdala and surrounding regions in the flower-image, mosaic, and fixation conditions. **(A)** Brain activation in the left amygdala (−30 0–18) was significantly decreased in the flower condition compared to the mosaic and fixation conditions ($P < 0.05$). **(B)** Activation of the right amygdala (24 −3 −18) did not differ among the three conditions. **(C)** Brain activation in the L Amyg–Hipp (−21 −6 −15) was significantly decreased in the flower condition compared to the fixation condition ($P < 0.05$). **(D)** In the right amygdala, including the hippocampus/parahippocampus region (33 −9 −15), brain activation was significantly decreased in the flower condition compared to the mosaic condition ($P < 0.05$). Brain activation tended to be lower during the flower condition than during the fixation condition ($P < 0.10$). *$P < 0.05$.

flowers needs to be examined further in the future.

5.3. Limitations and recommendations for future research

There are some limitations in the present study. First, we employed a typical flower image of a white chrysanthemum as the floral stimulus, to the exclusion of the numerous other types of flowers with different shapes, sizes, colors, and odors. Various flower types may induce different valences and arousal levels, and the recovery effects offered by the various flower types could likewise vary. On the basis of the present results, we conclude that reduced arousal and positive valence might be necessary characteristics of a stimulus intended to produce psychological and physiological stress-coping effects (Study 1). This interpretation should be developed to clarify the relationship between flowers and human emotions in detail. We hope that the present study may trigger investigation into the recovery effects of different types of flowers. Second, we could not clarify which areas showed increased activation during the attenuation of negative emotions through the passive viewing of flowers. To understand the contributions of prefrontal and parietal activation to automatic distraction, further studies with larger samples will be required. Third, the samples of our current studies involved young participants. The topic of age differences of the recovery effects with nature will be focused on in future studies.

6. Conclusions

First, the present study investigated the psychological and physiological recovery effects of viewing flowers after psychological stress. We demonstrated that negative emotion and elevated blood pressure were more effectively decreased during the viewing of a flower image than during the viewing of a mosaic image or fixation point in the absence of intentional control. Salivary cortisol was also downregulated in the flower condition as compared to the mosaic condition. These results suggest that passively viewing a typical flower image can lead to preferred states of emotion, automatic nervous system, and endocrine function after stressful events. Second, in our fMRI examination, we investigated brain-activation patterns relevant to unintentional emotional change during passive viewing of the typical flower image, and observed reduced activation in the right amygdala–hippocampus region while viewing the flower image compared to other stimuli. Our results suggest that viewing flowers can reduce activation in the amygdala–hippocampus and decrease negative emotion and physiological responses automatically. The simple strategy of viewing a flower after psychological stress could support recovery from stressful events in both psychological and physiological terms. The present results also imply that viewing a flower can induce automatic distraction and might help diminish several psychiatric or physiological risks, such as depression, anxiety, cardiovascular diseases or immune dysfunction, that are caused by chronic stress. The contribution of viewing flowers to human health should be examined in further studies.

CRediT authorship contribution statement

Hiroko Mochizuki-Kawai: Data curation, Writing - original draft, Formal analysis. **Izumi Matsuda:** Formal analysis, Software. **Satoshi Mochizuki:** Data curation.

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvp.2020.101445.

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