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The effect of hip-hop dance training on neural response to emotional stimuli

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SUMMARY

Many studies demonstrate that exercise improves mental health. However, the neural mechanisms underlying this improvement remain unclear. In the present study, we examined the effect of hip-hop dance training on neural response to emotional stimuli using the functional magnetic resonance imaging (fMRI) in healthy young adults. Twenty-two university students who did not regularly exercise were assigned to either the training group (7 men and 4 women) or the control group (5 men and 6 women). The training group performed short-term hip-hop dance training, consisting of a 60-min class 3 times per week for 3 weeks. The control group maintained their normal daily activity. Acquisition of fMRI was performed while the participants viewed pleasant, unpleasant, and neutral slides pre- and post-training. The contrasts of pleasant vs. neutral and unpleasant vs. neutral were calculated, and activity changes between the pre- and post-training periods were compared between the two groups. As a result, hip-hop dance training increased brain activity in the posterior parietal and occipital cortices, for both the pleasant and unpleasant emotional stimuli, suggesting that the training facilitated visual attention. Moreover, increased activity was observed in the temporoparietal junction (TPJ) and insula specifically for pleasant emotional stimuli, suggesting empathetic understanding of pleasant emotion, whereas no activity increase occurred in regions related to emotion generation for unpleasant emotional stimuli. These changes may be associated with psychological benefits of exercise.

Key words: exercise, mental health, neural substrate, fMRI, imaging.

Introduction

Many studies demonstrate that exercise improves mental health. These studies have reported the relationships between exercise and depression, anxiety, stress responsibility, mood states, self-esteem and other mental issues[1,23,29)]. Recently, meta-analyses of randomized controled trials have demonstrated that exercise is highly beneficial even in depressed patients[25,26)]. In addition, our previous studies have demonstrated that exercise acutely improves affective states in healthy young adults and schizophrenic patients[31)]. Furthermore, the long-term exercise reduces depressive symptoms in healthy young adults[13)]. It also reduces psychiatric symptoms and improves generalized self-efficacy in psychiatric patients[30)].

The mechanisms by which exercise improves mental health remain unclear. Elevated body temperature (the hyperthermic hypothesis), the release of endogenous opioids (the endorphin hypothesis), serotonin release (the monoamine hypothesis), a change in self-concept (the self-esteem and mastery hypothesis),

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and distraction are among the candidates for these mechanisms[1,23,29]; however, it has been difficult to adequately account for the psychological benefits of exercise.

The neural response to emotional stimuli is thought to be associated with mental health. For example, it has been suggested that depressed patients tend to exhibit abnormal brain activities during emotion processing[10,33]. In addition, pharmacological antidepressant treatments are reported to normalize these abnormalities[11,12]. Thus, changes in mental state are considered to be associated with the changes in neural response to emotional stimuli. Therefore, the improvement of mental health by exercise may be also associated with the changes in neural response to emotional stimuli. In the present study, we examined the effect of exercise training on neural response to pleasant and unpleasant emotional stimuli using event-related functional magnetic resonance imaging (fMRI) in healthy young adults. Whole brain analysis was performed to help understand the mechanisms underlying the psychological benefits of exercise.

In the present study, we selected hip-hop dance exercise for exercise training. Hip-hop dance was used because dance therapy has been known as a movement-based psychotherapy[20]. In addition, hip-hop dance exercise has been shown to improve affective states in healthy subjects, depressive patients, and schizophrenic patients[30,31].

Recently, the affinity between mental and bodily states has been reevaluated by the neuroscientific research. The neuroanatomical substrate for subjective feelings is based on an abstracted metarepresentation of the physiological state of the body[5,7,19]. Additionally, observation of others activates the mirror systems, which likely facilitate understanding of the emotions felt by others and what goes on in other[2]. Thus, emotional processing systems are intimately associated with the body and bodily states. We hypothesized that the psychological benefits of exercise might be associated with the changes in these body-related emotional processing systems. In addition, we hypothesized that hip-hop dance training might increase the neural response to pleasant emotional stimuli and not change the response to unpleasant emotional stimuli, because the previous work has shown that hip-hop dance exercise improves pleasure affect and does not change unpleasure affect in healthy young adults[31].

Methods

A. Subjects

Twenty-two subjects participated in the study. Right-handed sedentary university students were recruited. All subjects did not regularly exercise more than two times per week and did not have psychological and orthopedic problems. Written informed consent was obtained from all subjects. The study was approved by the Institutional Review Board of the Physical Fitness Research Institute, Meiji Yasuda Life Foundation of Health and Welfare, Japan.

B. Experimental design

Subjects were divided into a training group (7 men and 4 women) and a control group (5 men and 6 women). The training group participated in 60-min hip-hop dance classes 3 times per week for 3 weeks (9 classes in total). The control group maintained their normal daily activities and was specifically instructed not to start exercising during the experimental period. Affective states were measured in the training group before and after the first and ninth classes to confirm the effect of exercise on affective states. Acquisition of fMRI was conducted in two separate sessions, during the pre- and post-training periods (approximately 4 weeks apart). In the training group, the post-training scan was acquired 2 days after the final dance class. Both scans were acquired at the same time of day. During the fMRI acquisitions, the subjects performed an emotional stimulation task. The neuroimaging data acquired by fMRI were analyzed using Statistical Parametric Mapping software. The effect of dance training was tested using mixed-design two-way ANOVA, in which the different changes in the neural responses to pleasant and unpleasant stimuli between the two groups were compared through whole brain analysis. To measure the effect on mental health, the subjects completed self-reporting questionnaires measuring depressive symptoms after each fMRI acquisition.

C. Hip-hop dance training

The exercise intensity of hip-hop dance was approximately 65% of maximal heart rate (220−age)[31]. The lesson started with easy movements, and the skill level was gradually increased according to the level of subject's achievement. Because valuable and enjoyable experiences occur when perceived opportunities (challenges) are balanced with a person's perceived skills[8], a variety of hip-hop dance movements appropriate for the subject's skills was provided during the lessons. To minimize social contact and the influence of music, subjects were restricted from talking with each other and only one melody was used for rhythm perception throughout the 9 classes.

D. Event-related fMRI

Event-related fMRI was performed with a 1.5T Signa LX MRI unit (General Electrics, Milwaukee, WI, USA). Functional images of 136 volumes were acquired using T2*-weighted gradient-recalled echo planar imaging sequences sensitive to blood oxygenation level-dependent (BOLD) contrast. For each volume, 20 contiguous axial slice images were collected with the following parameters: TE, 90.5 ms; TR, 4000 ms; FOV, 240 mm; section thickness, 6.0 mm; matrix size, 128 × 128. We also acquired T1-weighted anatomical images for the purpose of spatial transformation of fMRI data. For the anatomical images, contiguous axial slices were acquired using a fast SPGR sequence with the following parameters: TE, 2.4 ms; TR, 26.0 ms; FA, 30°; FOV, 240 mm; section thickness, 2.3 mm; matrix size, 256 × 256. No structural abnormality was detected in any of the 22 subjects.

E. Emotional stimulation task

During fMRI acquisition, the subjects performed an emotional stimulation task. Stimulus materials were taken from the International Affective Picture System (IAPS), which was developed to provide a set of normative emotional stimuli for experimental investigations[18]. Emotional pictures were divided into three emotional categories (pleasant, unpleasant, and neutral) according to the subjective ratings provided by IAPS. We used 30 pictures from each category (90 slides total). The mean valence and arousal ratings (± SD) of the 30 pictures were 6.95 ± 0.50 and 4.45 ± 0.90 for pleasant, 5.38 ± 0.32 and 3.50 ± 0.51 for neutral, and 3.34 ± 0.77 and 4.21 ± 0.68 for unpleasant stimuli, respectively. The valences of pleasant and unpleasant pictures were significantly different from those of neutral pictures ($P < 0.001$, Student's t-test). Likewise, the arousals of pleasant and unpleasant pictures were significantly different from those of neutral pictures ($P < 0.001$, Student's t-test). All pictures consisted of human faces or figures. Pleasant slides included happy and joyful pictures, while unpleasant slides included sad and melancholic pictures. Disgusting, frightening, and erotic slides were excluded because of their high arousal potential. Appendix details the IAPS slide identification number, as well as normative ratings of valence and arousal, for each slide[18]. The pictures were projected via a computer and a telephoto lens onto a screen with a mirror mounted on a head coil. Each emotional slide was presented for 3 s, followed by interstimulus slides with a fixation cross for 3 s. Ninety slides were presented in random order. The subjects were instructed to observe the pictures and simply feel their emotions without considering what the pictures represented.

F. Neuroimaging data analysis

The data were analyzed using Statistical Parametric Mapping software (SPM2, Wellcome Department of Neuroscience, London, UK; available at http://www.fil.ion.ucl.ac.uk/spm). After correction for sectiontiming, all functional images were realigned to the first image in the time series to correct for head movements and then spatially normalized into the standard space defined by the Montreal Neurological Institute template. After normalization, all scans had a resolution of 2 × 2 × 2 mm. Functional images were spatially smoothed using a three-dimensional isotropic Gaussian kernel (full width at half-maximum of 8 mm). Low-frequency noise was removed by applying a high-pass filter (cut-off period = 128 s) to the fMRI time series at each voxel. Significant hemodynamic changes for each category were examined using a general linear model with a canonical hemodynamic response function. Two T-contrasts were calculated for each subject: pleasant versus neutral (response to pleasant emotional stimuli) and unpleasant versus neutral (response to unpleasant emotional stimuli). Random effect analysis was then performed using each individual's T-contrast images. For the random effect analysis, the effect of dance training was tested using mixed-design two-way ANOVA, in which the changes in each neural response to pleasant and unpleasant stimuli were compared between the two groups (population inference). The resulting significance values for each voxel indicate the likelihood of change in the hemodynamic response to emotional stimuli due to hip-hop dance training. Because the present study is the first attempt to examine the effect of exercise training on neural response using event-related fMRI, we performed explorative whole-brain analyses. The statistical threshold was set at $P < 0.001$ (one-tailed test), without multiple comparison correction. To avoid false positives, only clusters bigger than 10 contiguous voxels were considered. Anatomic labeling of the clusters was performed using Anatomic Automatic Labeling (AAL)[34].

G. Self-reporting questionnaires

In the first and ninth exercise classes, affective states were measured in the training group to confirm the improvement of affective states due to hip-hop dance exercise. Affective states were measured before and 5 min after the dance classes using a mood check list (MCL-S.2)[15,21]. The MCL-S.2 was developed to measure affective states during or after exercise. This questionnaire assesses pleasure, relaxation, and anxiety, and consists of 12 items (4 items for each dimension) scored on a 7-point (−3 to 3) Likert scale. In each dimension, the score ranges from −12 to 12 points. An increase in pleasure and relaxation and a decrease in anxiety indicate improvement in the affective state.

After each fMRI acquisition for the pre- and post-training periods, depressive symptoms were measured using the Center for Epidemiologic Studies Depression Scale (CES-D)[24,32], to examine the effect of the hip-hop dance training on mental health. The CES-D scale asks about the occurrence of 20 symptoms over the past week, and each response is scored from 0 to 3 (total score ranges from 0 to 60). A decrease in CES-D score indicates reduced depressive symptoms.

In the present study, all data are presented as means ± SD. Affective changes due to acute exercise (difference between before and after exercise) were tested using a paired t-test. The effect of exercise training on CES-D score was analyzed by mixed-design two-way ANOVA.

Results

The affective states before and after the first and ninth exercise classes are shown in Figure 1. A significant increase in pleasure (first session: 18.1 ± 4.0 to 22.8 ± 5.8, $P = 0.014$, ninth session: 16.4 ± 5.4 to 23.5 ± 4.7, $P = 0.004$) and a significant decrease in anxiety (first session: 12.5 ± 3.9 to 9.1 ± 5.5, $P = 0.020$) were observed immediately after acute exercise.

The CES-D scores pre- and post-training were 12.5 ± 6.5 and 13.6 ± 6.7 in the training group, respectively and 11.1 ± 4.8 and 12.3 ± 4.8 in the control group, respectively. No significant group-by-time interaction was observed ($P = 0.932$).

The effects of hip-hop dance training on neural re-

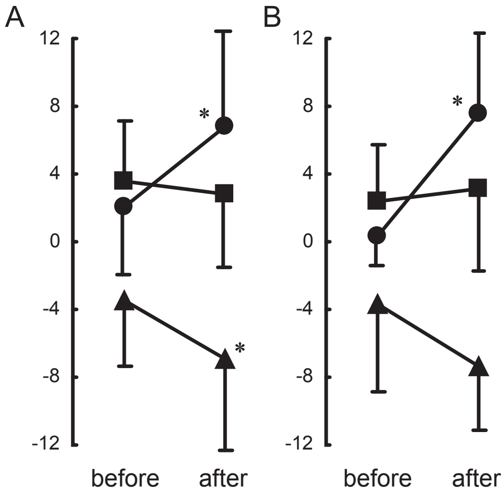

Figure 1. Affective states before and after dance classes.

A: first exercise session, B: ninth exercise session. The circle represents pleasure, the square represents relaxation, and the triangle represents anxiety. *: Significantly different from the baseline score for the same exercise session (paired t-test, $P < 0.05$). Affective states were measured using a mood checklist (MCL-S.2). Increases in pleasure and relaxation and a decrease in anxiety indicate improvement in mood. The scale range is −12 - 12. Data are expressed as means ± SD.

Table 1. Effects of exercise training on neural response (significant group-by-time interaction) to pleasant emotional stimuli.

Regions	L/R	Coordinate x	y	z	Z-value	Size
Regions showing increased activity						
Cuneus/SOG	L	−10	−82	28	5.40	240
Precuneus/Cuneus	R, L	6	−72	44	3.75	153
pMCC	R	12	−20	44	3.62	28
Insula	R	36	16	−4	3.59	37
TP/Insula	R	50	10	−10	3.57	46
Lingual/Cerebellum	L	−6	−66	−2	3.51	14
Angular gyrus	R	40	−68	44	3.36	28
Insula/Putamen	L	−26	16	−8	3.30	11
Lingual/PHG/Precuneus	R	20	−42	−2	3.26	17

SOG; superior occipital gyrus, TP; temporal pole; PHG: parahippocampal gyrus.

Table 2. Effects of exercise training on neural response (significant group-by-time interaction) to unpleasant emotional stimuli.

Regions	L/R	Coordinate x	y	z	Z-value	Size
Regions showing increased activity						
SPL/IPL	L	−28	−60	54	4.10	92
Postcentral gyrus/PCL	R	14	−38	64	3.67	25
Precuneus	R	6	−74	50	3.25	23

PCL; paracentral lobule.

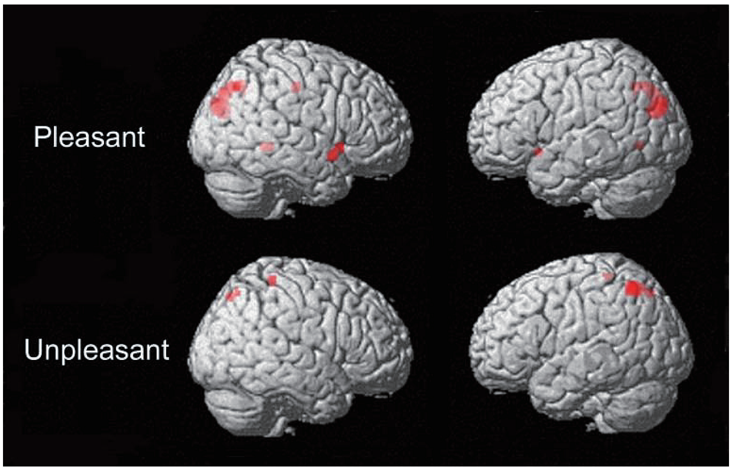

Figure 2. Regions showing significant group-time interactions (red blobs show increased brain response in the training group compared with the control group) are projected onto a single template brain.
The top left and right panels show increased neural responses to pleasant emotional stimuli, and the bottom left and right panels show increased neural response to unpleasant emotional stimuli. The views are from the right (top and bottom right) and the left (top and bottom left).

sponse to pleasant and unpleasant emotional stimuli are listed in Table 1 and 2. Significantly enhanced responses in the training group compared with the control group (group-time interactions) were observed in following regions: cuneus, precuneus, insula, temporal pole, putamen, posterior midcingulate cortex (pMCC), and angular gyrus for the pleasant emotional stimuli; superior parietal lobule (SPL)/inferior parietal lobule (IPL), cuneus, and somatosensory region for the unpleasant emotional stimuli. The cluster of increased activity in the cuneus [x, y, z = −10, −82, 28] for pleasant emotional stimuli survived with a statistical threshold of $P < 0.05$ corrected for multiple comparisons (controlling family-wise error rate: FWE correction). The projection of the clusters onto a single template brain is shown in Figure 2. No regions were observed in which the neural response decreased in the training group compared with the control group.

Discussion

In the present study, we examined how hip-hop dance training influences the neural response to emotional stimuli in healthy young adults. The results showed that hip-hop dance training activated the neural response in several areas consistent with the improvement of affective state. The improvement of depressive symptoms was not observed in the present study.

In each exercise class, subjects experienced the improvement of affective states (increased pleasure and decreased anxiety). Therefore, the hip-hop dance exercise was a sufficient stimulus to improve the mental health. However, improvement of CES-D score was not observed in the present study (9 exercise classes). In our previous study, a long-term intervention (30 exercise classes) improved CES-D score in healthy young adults[13]. Therefore, to improve depressive symptoms, a longer training period than that employed in the present study might be needed. Otherwise, changes in neural response to emotional stimuli may precede the improvement in depressive symptoms measured by the CES-D scale.

Activated neural responses were observed in several clusters in the posterior parietal cortex (precuneus, SPL, IPL, angular gyrus) and occipital lobe (cuneus, SOG) to both pleasant and unpleasant emotional stimuli. The posterior parietal cortex is located between the postcentral gyrus and visual cortex in the occipital lobe. It is well-positioned to bridge the visual and somatosensory inputs and to provide sensory control of action via output to the frontal (pre) motor area[35]. Accordingly, these areas may be involved in visual information processing of stimuli, suggesting the facilitation of visual attention to the emotionally salient stimuli. The angular gyrus, which increased activity only to pleasant emotional stimuli, is known as a part of the temporoparietal junction (TPJ). The TPJ plays a role in the "Theory of Mind," the ability to attribute mental states, such as thoughts and beliefs, to oneself and others[27,28]. The TPJ also plays a critical role in the distinction between self-produced actions and actions generated by others[3,16]. Such functions are crucial for empathy (sharing the feelings of others)[9]. Specific changes to the processing of pleasant emotional stimuli in the TPJ may shift recognition bias to positive emotional stimuli, which may be associated with the psychological benefits of exercise. Other clusters in the posterior parietal cortex seem to process emotional visual information. The precuneus, SPL and IPL are sometimes activated like mirror systems. Previous reports suggest that the observation and mental simulation of reaching and grasping actions, which require the integration of visual and proprioceptive information, activate the precuneus, SPL and IPL[35]. We speculate that increased activity in these areas is associated with enhanced processing of emotion expressed from the body in the pictures. The cuneus, located in the occipital lobe, is known for its involvement in basic visual processing. This area is also reported to increase its activity to a greater degree in response to emotion expressed from the body than to emotion expressed from the face[17].

Mirror systems are considered to play an important role in the understanding of others[2]. Seeing the emotions of others recruits motor and somatosensory components. In the present study, increased activity was observed in the pMCC (to pleasant emotional stimuli) and somatosensory region (to unpleasant emotional stimuli). The pMCC projects to the spinal cord, regulates skeletomotor function, and interacts with the posterior parietal cortex[36]. The activity of mirror systems is plastic; for example, greater mirror system activity is observed when the expert dancers (ballet and capoeira dancers) view movements that they have been trained to perform[4]. Therefore, the activated neural responses in the pMCC and somatosensory region were thought to have resulted from hip-hop dance training.

Along with changes in the mirror systems, changes in the insular cortex were also observed. The physiological condition of all organs of the body (muscles, joints, skin, and viscera) provided through the lamina I spinothalamocortical pathway[5] is represented in the insular cortex. This cortex engenders all subjective feelings and emotions, which reflect the integrated whole-body physiological state[7]. In addition, activations of this area play an important role in transforming observed emotional states into experienced states. In the present study, changes of activity in the insular cortex were only observed for pleasant emotional stimuli. The results suggest that hip-hop dance training increased the feeling of pleasant emotions at the level of internal experience. Additionally, the role of anterior insular cortex (AIC) seems to have left-right asymmetry. Stimuli that activate the right AIC are generally arousing to the body (for example, pain), while the left AIC is activated mainly by positive and affiliative emotional feelings[7]. This asymmetry seems to derive from the asymmetry of the autonomic nervous systems; the right AIC controls sympathetic activity, while the left AIC controls parasympathetic activity[6]. In the present study, exercise training increased activity in the bilateral AIC to pleasant emotional stimuli, which was considered as activated sympathetic and parasympathetic activity to pleasant emotional stimuli. Furthermore, neuroimaging studies have revealed that the insular cortex is involved in various neuropsychiatric diseases such as mood disorders, panic disorders, and PTSD[22]. Therefore, the insular cortex seems to play an important role in maintaining mental health, and the changes in insular activities specific to pleasant emotional stimuli were considered to be associated with the psychological benefits of exercise.

The present study was limited by the low statistical threshold used in neuroimaging analysis, which was chosen due to the work's exploratory nature. Further study with a stricter statistical threshold is needed to clarify the effect of exercise training on neural response to emotional stimuli. Additionally, we focused on the comprehensive effects of hip-hop dance training; however, to assess only the effect of the physical and physiological stimuli of exercise, the influences of social contact and music should be controlled. We hypothesize that the nonverbal communication and entertainment aspect of exercise (in hip-hop dance exercise, rhythmic movements with music) are also important factors for exercise to improving mental health. We believe that how one feels during exercise was important for improving mental health[14].

Conclusions

We examined how hip-hop dance training influences neural response to emotional stimuli in healthy young adults. Activated neural responses were observed in the posterior parietal and occipital cortices, to both pleasant and unpleasant emotional stimuli. Furthermore, in accordance with our hypothesis, the hip-hop dance training activated a neural response specifically to pleasant emotional stimuli in the TPJ and insular cortex. These changes may be associated with the psychological benefits of exercise.

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Appendix Identification number, valence, and arousal of slides derived from International Affective Picture System.

Pleasant			Neutral			Unpleasant		
ID#	Val	Aro	ID#	Val	Aro	ID#	Val	Aro
2040	7.63	4.33	2038	5.08	2.98	2095	2.16	4.69
2050	7.80	4.05	2102	5.19	3.12	2104	4.42	2.91
2070	7.69	4.02	2191	5.49	3.63	2141	2.72	4.40
2154	7.87	4.58	2214	4.83	2.77	2205	2.24	4.41
2224	6.78	4.59	2270	5.39	3.07	2210	4.41	2.72
2299	6.75	3.93	2305	5.71	4.27	2221	4.47	3.11
2303	6.51	5.00	2357	5.33	3.06	2271	4.34	3.56
2339	6.62	4.33	2372	5.35	3.39	2276	3.17	4.02
2340	7.65	5.35	2383	4.62	3.49	2278	3.39	4.39
2341	6.78	3.59	2394	5.36	3.85	2312	4.00	3.77
2344	6.06	4.11	2397	5.06	3.12	2399	3.90	3.71
2345	6.91	4.60	2435	5.70	4.03	2455	3.32	4.26
2370	6.71	2.85	2487	5.09	3.74	2490	3.96	3.83
2387	6.52	3.84	2495	5.35	2.72	2491	4.33	3.48
2391	7.33	5.50	2500	5.83	3.66	2520	4.12	4.19
2501	6.33	2.67	2513	5.65	3.41	2590	3.04	4.00
2510	6.66	4.15	2515	5.70	3.62	2700	3.33	4.52
2530	7.25	4.23	2516	5.11	3.59	2703	2.33	5.73
2550	7.37	4.15	2518	5.38	3.21	2710	3.04	5.29
2598	6.75	3.76	2579	5.70	3.91	2715	3.60	3.99
4614	6.38	3.72	2580	5.45	2.72	2716	3.48	5.21
8320	6.33	4.46	2600	5.92	4.37	2718	4.00	4.04
8330	6.22	3.87	2620	5.73	3.04	2750	2.57	4.06
8350	6.80	4.94	2635	5.26	4.45	2753	3.73	3.93
8380	7.25	6.02	2690	5.08	3.85	2795	4.09	4.37
8490	6.85	6.25	2702	5.78	4.28	2799	2.76	4.75
8496	7.09	5.00	2749	5.15	3.70	2800	2.31	4.94
8497	6.76	3.89	2830	5.09	3.93	2810	4.56	4.33
8499	7.51	6.69	4532	5.15	2.73	2900	2.76	4.76
8540	7.28	4.96	5410	5.78	3.42	9421	2.47	4.86

ID#; the IAPS slide identification number, Val; normative valence ratings, Aro; normative arousal ratings.