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Investigating the Impact of Coloring Experience on Young Adults Through Brainwave Variations and Image Preferences

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In this pilot study, the aim is to explore "which images have a good focus and relaxation level" and "whether the gender influences the preference and brainwave." The coloring books were used to investigate differences in subjective preference and physiological responses between young male and female adults. Semi-figurative and abstract images were employed to study 60 young adults, including 30 girls and 30 boys. The experimental results revealed that both genders exhibited a significant improvement in focused attention and relaxation levels when coloring the semi-figurative images. However, no significant electroencephalography (EEG) differences were observed when young male and female adults coloring the two images. This indicates that subjective preferences and gender do not affect the focused attention and relaxation levels experienced during coloring.

Keywords: wearable electroencephalography (EEG) device, attention, stress-reduction level, coloring book

Introduction

Adolescents and young adults commonly experience emotional problems caused by various stress factors (Alshahri, 2016; Chang, Lin, & Yeh, 2010; Martyn-Nemeth et al., 2009). Therefore, this study was used coloring books to improve their relaxation levels. Recently, coloring books have become prevalent. They are no longer merely restricted to children or adults learning or practicing to draw, but have been applied to adults in the form of mandala art, which can help them to reduce stress during coloring. Coloring books generally contain an abundance of attractive images, lines, and shapes. By filling colors into the predesigned patterns, users are able to shift attention to coloring the preprinted lines and shapes. These pre-designed patterns prevent unskilled drawers from generating anxiety because of drawing failure (Carsley, Heath, & Fajnerova, 2015).

Stress and anxiety mainly originate from future uncertainty or regret for past actions. Drawing enables a person to meditate on the present by refocusing attention and relaxing the mind. Psychologists refer to this high-focused mental state as flow. Tadayon and Afhami (2016) claimed that doodling assists in enhancing students' focus and learning effectiveness. A state of meditation, resulting from high-focused attention, reduces stress and improves well-being (Goyal et al., 2014; Khoury, Sharma, Rush, & Fournier, 2015). Mandala art is frequently used as a supportive method in art therapy. The term "mandala," originating from Sanskrit, refers to a sacred circle or axial center. Initially, it was used for religious or ritual purposes. Later, the Swiss psychiatrist Carl Jung (1938), through observing his mandala drawings, found that the drawings corresponded to his inner

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states and enabled him to explore the unconscious self. Thus, he applied the making of mandala art to psychotherapy. Clinical dream analyses have suggested that mandala is a representation of creator and preserver. It prevents a patient from being in psychological chaos and integrates states of consciousness (Capuzzi & Gross, 2014). Mandalas are often created during the reintegration of inner states, assisting a patient to explore their mind through observing the mandalas they have created (Fincher, 2007). The colors used in creating the mandalas can also be observed to identify a subject's potential psychological conditions (Kim et al., 2014). However, this study is different from the common way to create the mandala and we just use the mandala image to design the sample.

Literature Review

This study explored the differences in subjective preferences and physiological responses among young adults during coloring. Thus, test subjects were requested to color images that featured pre-designed patterns rather than create images with desired patterns. Drawing is an ideal method of expressing emotions, because images are symbols used in visual communication that help people to think and perceive, and provide a sense of perfection, harmony, and order. Generally, human brains process images in three stages (Solso, 2003). The first stage is a physical phenomenon affected by the quality and quantity of light. The second stage is physiological, because color information is transmitted to the brain after the visual cells undergo color-matching responses to the light stimuli. The third stage is a psychological transition where variations in consciousness occur after the brain perceives light.

Coloring books available on the market generally feature semi-figurative or abstract images. Semi-figurative images are often created through simplifying or extracting the elements of figurative objects, rendering the images to represent aspects of both figurative and abstract forms. They are more easily understood than abstract images and are more unique-looking than figurative images (Norman, 1998). Abstract images are constructed using simple points, lines, and planes, exuding characteristics of rationality, orderliness, and simplicity to the viewer (Meyer & Laveson, 1981). Therefore, once the eyes are stimulated, people are able to assign meanings to a series of images not only by their basic ability to select and assemble, but also through complex psychological activities, that is, to detect, memorize, understand, and think (Gerrig & Zimbardo, 2004).

Several scholars have developed brain science theories and have conducted various studies to elaborate on the importance and relevance of brain science. Presently, medical studies have confirmed that brain activities, including thinking, emotions, and desire, can be presented through electronic and chemical reactions. In addition, electroencephalography (EEG) can be employed to generate diagrams by showing brainwave patterns. Brainwaves are the electrical currents generated in the brain. The electrical activity of the brain can be rendered into an electroencephalogram. Hans Berger (1873-1941) divided normal brainwaves according to frequency into four types: α, β, θ, and δ waves (Haas, 2003). When an individual enters a state of relaxation, the following physiological reactions are generally detected: (a) reduced heart rate and blood pressure; (b) increased α-wave; (c) boosted confidence; and (d) improved concentration (Klimesch, Schimke, & Pfurtscheller, 1993). Thus, scholars in this field tend to apply this concept of brainwave division to analyzing brainwaves, which are categorized according to their frequency (see Table 1).

In addition to regular questionnaire surveys, using data on skin conductance response, facial expressions, heart rate, and electroencephalograms has recently become a widespread approach for emotion modeling (Wu, Huang, & Hwang, 2016). In the present study, an EEG device was employed as an auxiliary research tool, because it directly detects human physiological responses (e.g., brainwaves, heart rate, blood pressure, and breathing) that cannot be easily manipulated unless the subjects have participated in special training for brainwave self-control (Antonenko, Paas, Grabner, & van Gog, 2010). Additionally, α-wave is associated with problem solving and exhibit a positive correlation with positive moods (Bhattacharya et al., 2016; Vecchiato et al., 2011), while β-wave amplitude serves as an indirect indicator for measuring alertness, which can be used to detect fatigue levels, with a higher β-wave amplitude representing greater alertness (Jap, Lala, & Fischerb, 2011; Lees, Khushaba, & Lal, 2016; Poupard, Sartène, & Wallet, 2001). Brainwaves have been used in various fields as an indicator of physiological conditions. For instance, Chen, Wang, and Yu (2015) employed brainwave detection technology in video lecturing, in which real-time brainwave signals were used to assess students' attention levels and enable the instructor to remind the students to focus their attention. Moreover, brainwaves have been used to understand the purchase decision-making process (Khushaba et al., 2013) and treat depression through detecting brainwave variations in various contexts (Ramirez, Palencia-Lefler, Giraldo, & Vamvakousis, 2015; Tilley, Neale, Patuano, & Cinderby, 2017). Fraga, Pichiliani, and Louro (2013) measured brainwave variations from test subjects reading books to calculate and visually present human affective states and to channel into language and artistic fields by collecting human precepts to understand human mind activity. Compared with conventional EEG equipment that is cumbersome and non-portable, this study employed a modern wearable EEG device, which is more affordable and flexible, allowing scholars to apply their use in various fields.

Table 1

Comparison of Brainwave Frequency

Type	α-wave		β-wave		θ-wave	δ-wave	γ-wave
Frequency (HZ)	8-12	12-15	15-18	18-30	4-8	< 4	25-100
Corresponding states	Relaxed, and awake with eyes closed	Relaxed but focused	Thinking and processing external signals	Excited and anxious	Experiencing emotional stress (adults)	In deep sleep without dreams	Increased consciousness and meditation

Methodology

A semantic differential scale, questionnaire, and experiment were employed. Means (*M*s) were used as an indicator for testing subjects' perceptions toward the images. To prevent subjects from seeing the same image, affecting their psychological perceptions, bestselling images were re-designed and used as samples for the subjects, who were requested to view various styles of patterns and fill out a semantic differential scale and questionnaire. A sample for each subject was chosen at random. After putting on a wearable EEG device and ensuring correct signal status, the subjects began the coloring experiment. Experiment data were collected and analyzed to explore young adults' preferences for image levels, attention levels, and stress-reduction levels. The research framework is illustrated in Figure 1.

The test subjects were 60 young adults aged 18-22 years old. After excluding the subjects whose brainwave signals became unstable, the batteries ran low or inadvertent detachment of the device occurred, and the device slipped off due to forehead grease, 30 male and 30 female subjects were retained. Before completing a semantic differential scale and questionnaire, the subjects were requested to view a semi-figurative (see Figure 2) and abstract (see Figure 3) images. These two images, though of different styles, were both presented with patterns that expand from the center to the periphery and were used to examine the subjects' semantic perceptions and image preferences.

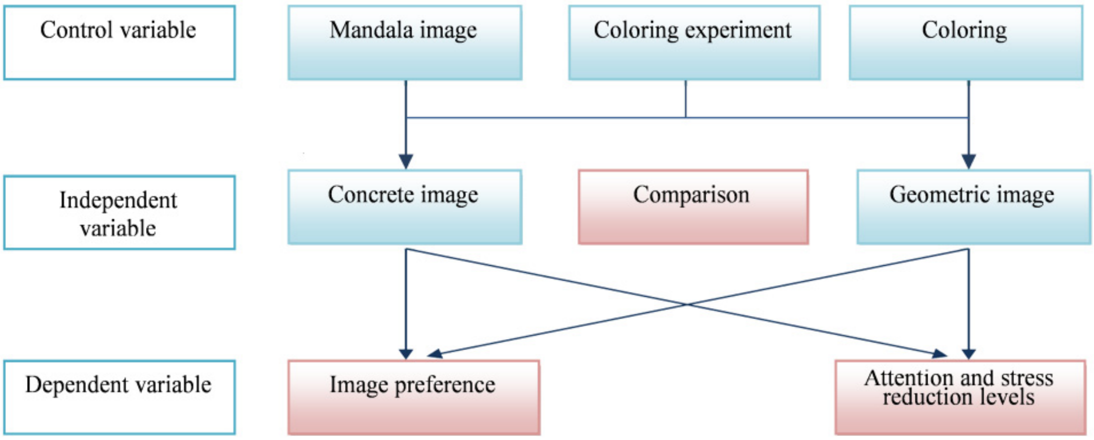

Figure 1. Research framework.

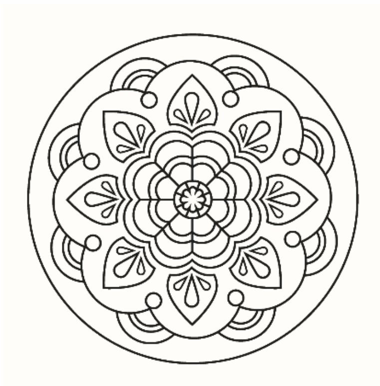

Figure 2. A concrete image.

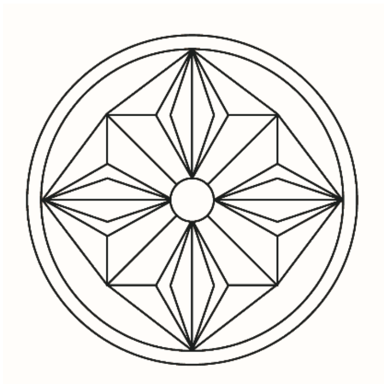

Figure 3. A geometric image.

During the EEG experiment, a wearable EEG device (NeuroSky Mindwave) was used to measure subjects' attention and relaxation levels. This non-invasive device included Frontal Pole (FP) 1 and FP 2 prefrontal electrodes and covered five EEG frequencies (δ, θ, α, β, and γ). To collect numerical data for young adults' attention, stress-reduction levels, and e-sense, NeuroSky's proprietary algorithm developed on the basis of numerical parameters, was employed to present subjects' attention levels through concrete numbers ranging from 0-100. Numbers 40-60 indicated a normal attention level, numbers 60-80 suggested a slightly higher than normal level, and numbers 80-100 represented a highly focused attention level. Numbers 20-40 and 0-20 meant a slightly low attention level and a low attention level, respectively, suggesting that subjects experienced various levels of nervousness, impatience, and disturbance. Figure 4 illustrates a section of EEG diagram, showing attention and stress-reduction variations.

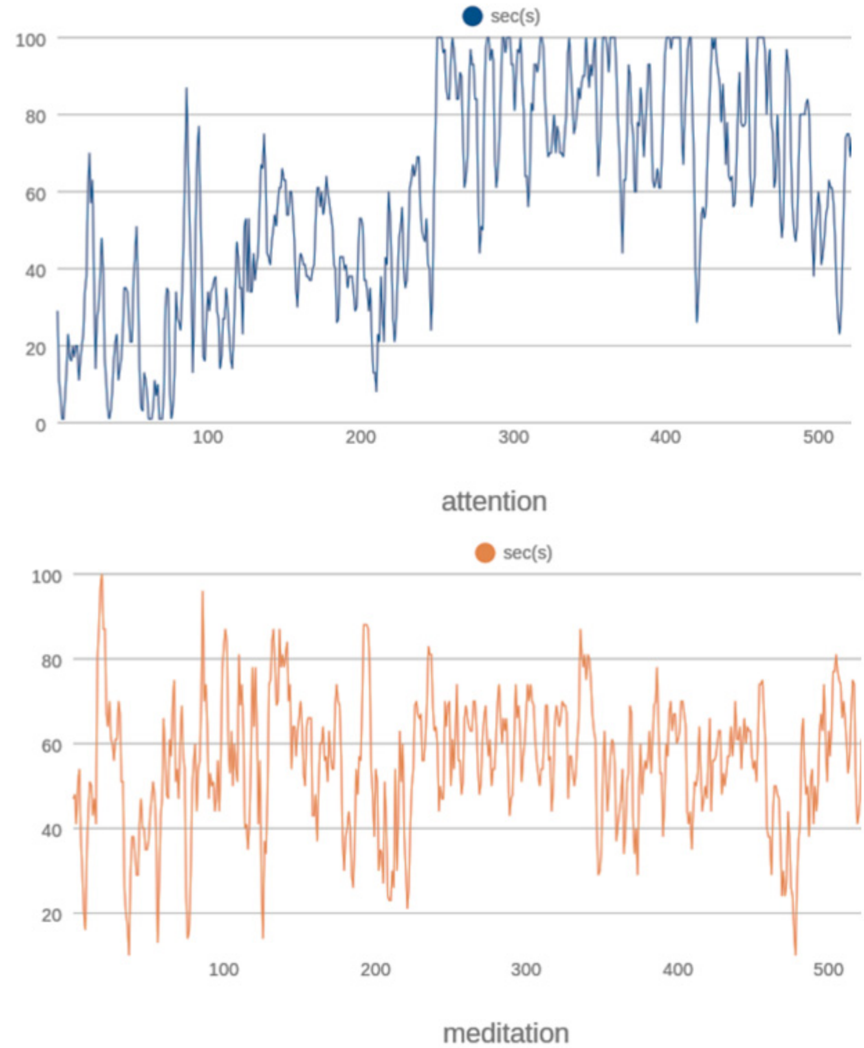

Figure 4. EEG diagrams for attention and stress-reduction levels.

The experiment was conducted in a laboratory, featuring a quiet and undisturbed environment. One day before the experiment, the subjects were requested to fulfill a number of tasks, such as avoid exercise or other attention-consuming activities that may impact brainwave collection on the experiment day. Before commencing the actual experiment, they were asked to stay relaxed, and under the test operator's guidance, assist in the implementation of the experiment and EEG data collection. The subjects received assistance in putting on the EEG device before beginning the coloring of images. Their data were then closely monitored during the experiment, in which they completed image coloring (see Figure 5).

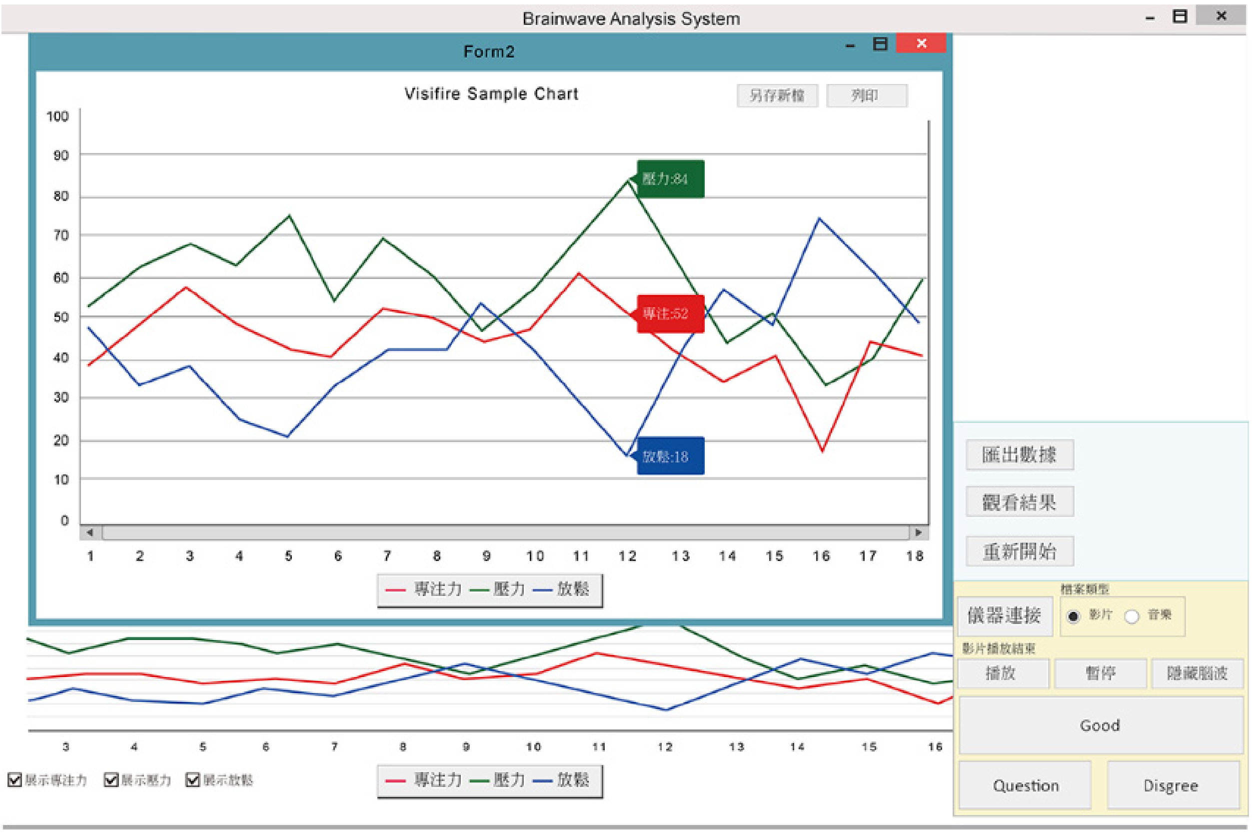

Figure 5. Experiment procedures.

A semantic differential scale and questionnaire (used for investigating image preferences) were employed to understand young adults' subjective perceptions toward images. EEG data were collected by using the EEG device and analyzed. A one-sample *t*-test was used to examine whether the subjects' perceptions and preferences collected from the scale and questionnaire conformed to the data collected by using the EEG device.

Results

To explore the young adults' brainwave variations during image coloring, a semantic differential scale and questionnaire were employed to investigate the subjects' subjective preferences. Also, a wearable EEG device was used as an objective evaluation tool to compare the subjects' subjective perceptions before the experiment with the physiological data collected during the experiment. The subjects' data regarding their perceptions toward semi-figurative and abstract images were reproduced as a broken line graph (see Figure 6), which can be used to understand the distribution of young adults' perceptions toward these two types of image. The overall visual perception broken line graph indicated that the subjects of both genders exhibited noticeable perceptions of attraction (i.e., being attracted; M = 3.51), complexity (M = 5.5), nervousness (M = 4.56), and fretfulness (M = 4.56) toward images. Among these perceptions, attraction exhibited substantial statistical significance with other perceptions. The same graph suggested that subjects of both genders exhibited noticeable perceptions of attraction (M = 3.5), simplicity (M = 2.75), relaxation (M = 3.06), and calmness (M = 3.15). However, no statistical significance was observed among all perceptions toward abstract images.

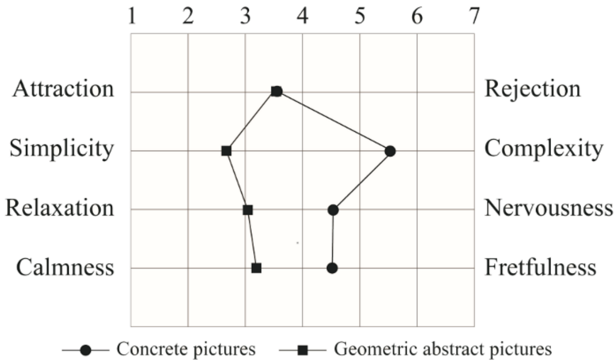

Figure 6. A broken line graph illustrating overall visual perceptions toward concrete and geometric mandala images for subjects of both genders.

A one-sample *t*-test was used to examine whether attention and stress-reduction levels exhibited significant differences between coloring semi-figurative and abstract images. Table 2 illustrates a statistical analysis, comparing attention levels, when coloring the two types of mandala images, showing a statistical significance for semi-figurative images ($p = 0.001$).

Both images exhibited a mean difference higher than 50, representing a baseline attention level. However, attention levels were generally higher in coloring semi-figurative images than in abstract ones, which can be attributed to the lines and composition of semi-figurative images being more detailed than those of abstract ones. Therefore, subjects were relatively focused on contemplating strategies for coloring the semi-figurative images, which can be presented by using more color schemes and have more room for contemplation. Table 3 presents a comparison of stress-reduction levels between coloring semi-figurative and abstract images, suggesting a statistical significance for both images ($p < 0.05$).

Table 2
Comparison of Attention Levels Between Coloring Concrete and Geometric Mandala (*Test value* = 50)

	T	*df*	*Sig.* (2-tailed)	Mean difference
Concrete	3.534	29	0.001**	6.01892
Geometric	2.029	29	0.052	2.77361

Note. ** $p < 0.05$.

Table 3
Comparison of Stress-Reduction Levels Between Coloring Concrete and Geometric Mandala (*Test value* = 50)

	T	*df*	*Sig.* (2-tailed)	Mean difference
Concrete	3.543	29	0.000**	6.00774
Geometric	3.450	29	0.002**	4.97771

Note. ** $p < 0.05$.

Both images exhibited a mean difference higher than 50, representing a baseline stress-reduction level. However, stress-reduction levels were generally higher in coloring semi-figurative images than in abstract ones, which can be attributed to the necessity to be focused on color choices and to fill in a higher number of intricate blank areas in coloring semi-figurative images. Therefore, subjects alternated colors more frequently and stayed relatively focused when coloring semi-figurative images, whereas they tended to be interrupted by other thoughts when coloring abstract images, which involved larger blank areas and thereby required a longer time by using a color.

An independent sample *t*-test was conducted to examine whether a statistical significance can be found from the collected EEG data. Table 4 displays the results of this *t*-test on male and female subjects, showing attention levels for coloring semi-figurative images (t = -0.577, p = 0.569) and abstract images (t = -1.779, p = 0.086), and stress-reduction levels for coloring semi-figurative images (t = -3.541, p = 0.135) and abstract images (t = -0.954, p = 0.348). This shows that there was no statistical significance in the EEG data from either male or female subjects when coloring the two types of images, thereby failing to confirm this study's hypothesis. This failure can be explained by a disparity between preferences prior to the experiment and coloring behavior during the experiment. For example, although a significant difference in image preferences between male and female subjects was observed, all subjects were focused on completing the task of coloring both images, resulting in a lack of significant differences between coloring both images.

Table 4

Independent Sample T-Test on Male and Female Subjects

		Leven's test for equality of variances		*t*-test for equality of means		
		F	*Sig.*	*T*	*df*	*Sig.*
Attention level (concrete)	Equal variances assumed	0.065	0.801	-0.577	28	0.569
	Equal variances not assumed			-0.577	27.983	0.569
Attention level (geometric)	Equal variances assumed	1.047	0.315	-1.779	28	0.086
	Equal variances not assumed			-1.779	25.530	0.087
Stress reduction level (concrete)	Equal variances assumed	0.202	0.657	-3.541	28	0.135
	Equal variances not assumed			-3.541	27.732	0.135
Stress reduction level (geometric)	Equal variances assumed	0.031	0.862	-0.954	28	0.348
	Equal variances not assumed			-0.954	26.618	0.349

The hypothesis of this study was that differences in attention and stress-reduction levels would be observed between male and female subjects coloring semi-figurative and abstract images. The results of the independent sample *t*-test indicated that there were no significant EEG differences between male and female subjects coloring the two images. However, for both male and female subjects, higher attentional and stress-reduction levels were observed in coloring semi-figurative images than in coloring abstract images. According to the questionnaire results, female subjects preferred semi-figurative images, mainly because these images featured richer and more varied patterns than did abstract ones, whereas male subjects favored abstract images because these simple-looking images tended to generate perceptions of relaxation.

Conclusion

Electrical potential differences caused by cognitive and emotional brain activity can be used as a physiological measurement tool for evaluating changes in mental processes. Therefore, a wearable EEG device was employed to explore subjects' visual perceptions toward coloring bestselling images through examining EEG variations. The following four conclusions can be made:

1. The results of semantic differential analysis indicated that, for subjects of both genders, semi-figurative images generated more positive semantic perceptions overall than did abstract ones. However, the questionnaire results showed that female subjects preferred semi-figurative images, whereas male subjects

favored abstract ones. The results of the experiment confirmed that, on a visual level, differences in the visual cortex and photoreceptor cells between both genders result in perceptional and preferential disparity, explaining why women prefer two-dimensional (2D) and decorative images, whereas men favor abstract images (Kimura, 2002; L. Salkind & N. J. Salkind, 1997).

2. The results of EEG data analysis suggested that subjects of both genders exhibited baseline attention and stress-reduction levels in coloring either semi-figurative or abstract images. There is no significant differences were observed when coloring the two images, implying that the only difference in visual perceptions toward the images between male and female subjects was observed in their subjective perceptions. During the process of coloring, no differences in physiological signals were observed between the two genders.

3. A comparison of attention and stress-reduction levels between males and females coloring both images illustrated that all means of these two levels detected from male subjects were higher than those from female subjects.

4. Because the amount of EEG data collected was very large, this study did not explore other dimensions of images (e.g., color, composition, and form). In addition to attention and stress-reduction levels, follow-up studies may focus on other forms of emotion (e.g., facial expressions) and color choices during the process of coloring. By employing subjective questionnaires and conducting an experiment through using an EEG device, this study investigated young adults' image preferences during the process of image coloring by detecting their physiological responses. This paper is a pilot study and provides encouragement for future studies to generate further findings that can contribute to the field of art therapy.

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