EEG Based Artistic Visualization of Dreams

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ABSTRACT

The purpose of this research is to explore the artistic visualization of dreams based on human electroencephalogram(EEG) data during REM sleep, and the generation of analytic dream-related images through a computer algorithm. This study utilized a polysomnography EEG monitoring device to keep track of the sleep activities of 11 subjects, primarily extracting objective data from the dreaming stage. Subjective measurement such as psychological questionnaire was also applied to assist in emotion evaluation to eventually generate an abstract visual expression of dreams. The study discusses a method of creating visual images of dreams based on objective EEG data signals combined with subjective emotion evaluation, providing a new path for the explicit visual expression of implicit conscious activities.

CCS CONCEPTS

• **Human-centered computing**; • **Visualization**; • **Visualization design and evaluation methods**;

KEYWORDS

Dream visualization, Brain art, Electroencephalogram, Emotion visualization

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1 INTRODUCTION

The research on dreams in modern times mainly includes the psychoanalytic school represented by Freud and the modern sleep science based on EEG signals and physiological indicators. The publication of "Analysis of Dreams" by the Austrian psychologist Sigmund Freud marked the beginning of a systematic exploration of dreams in the modern sense.[1] He reduced the essence of dreams to "satisfaction of desires." Carl Gustav Jung further elaborated on Freud's point of view, that dreams are partial close-ups of people's complex mental activities.[2] In the late 1950s, with the rise of cognitive science and neurobiology, the interpretation of dream content was replaced by scientific experimentalist theories. Nathaniel Kleitman and his student Eugene Aserinsky discovered the regular cycle of sleep (REM) At the same time, it proved that "rapid eye movement" is related to the general increase in dreaming and brain activity, which has greatly promoted the progress of dream research.[3] Subsequent experiments by Kleitman and William C. Dement found that the electrical activity of the brain measured by EEG in the REM phase is very similar to the active saccade of the waking eyes, and there is a high correlation between rapid eye movement sleep and dreaming (0.80 correlation coefficient). The instrument testing is introduced into sleep and dream testing.[4]

In this paper, the exploration of dreams is based on EEG data, combined with the semantic model of mental and emotional representation, to explore the operating mechanism of the visual abstract art of dreams. Today's brain-computer art increasingly uses technologies such as immersive virtual reality, large display screens, and audio-visual mixing to enable participants to obtain other sensory experiences. Although the exploration of dreams can take various forms, the study of brain physiological data from the artistic path is expected to convey concepts that are difficult to clarify in dream research through the emotional power of art and transform them into creative paintings combining with aesthetic value.

1.1 Related Research

Common neuro-brain imaging techniques include electroencephalography (EEG), magnetic resonance imaging (MRI), functional near-infrared optical imaging (fNIRS), and magnetic brain imaging (MEG). Among them, EEG measures the electrical signal generated by neural activity through the electrode array distributed on the scalp, which is considered to measure the direct neural signal, which has the characteristics of high timely response (millisecond level) and low spatial resolution. The portability and miniaturization of EEG equipment meet the requirements of this research, and its high time resolution is suitable for real-time visualization of neural oscillation inside our brain. In addition, the objectivity of EEG data has also attracted wide attention for its application in the field of emotion recognition.[5] EEG signals are highly correlated with emotions and have a strong ability to distinguish emotions. Thus, it's suitable for the visualization study of implicit consciousness activities such as dreams.[6]

As early as 2001, Fosse et al. used EEG and fMRI (Functional Magnetic Resonance Imaging) to prove that there is a high correlation between the emotional processes that occur in sleep and the

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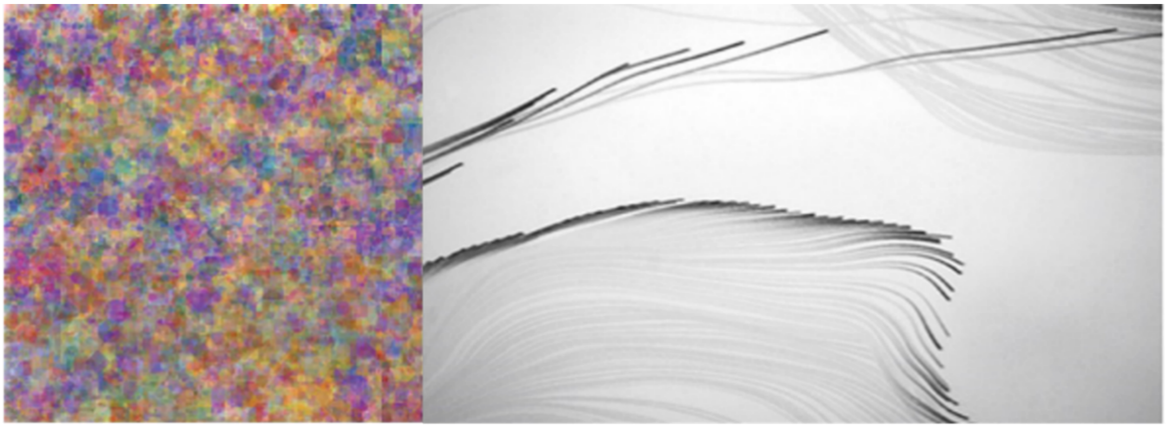

Figure 1: (L) The artwork of ABSTRACT Visualization of Sleeping Brain.[12] (R) The artwork of Taoist Data Visualization.[13]

emotional function of waking.[7] In 2017, Marquis et al. detected frequent nightmare(NM) recallers' wakefulness and EEG spectrum activity during sleep and found that the EEG activity of sleep θ waves was higher, mainly at the frontal and central electrodes, especially obvious during REM sleep. The results of this study support the role of theta waves in emotional processing during REM sleep.[8] In 2019, Pilleriin et al. used EEG to explore how frontal lobe alpha asymmetry (FAA) is related to dreaming emotions. The relative difference in frontal alpha power is related to emotional processing and emotional regulation during wakefulness. During REM sleep and waking up at night, people with stronger FAA experience more angry emotions in their dreams. Therefore, FAA may reflect the ability to regulate emotions not only in a waking state but also in a dreaming state.[9] In 2020, Nokia Bell Labs' Alessandro Fogli et al. designed a "scoring" system based on psychology to calculate multiple "emotional scores" for each dream: for example, the aggression in the dream, or the relationship between negativity and positive emotions. Compared with the score calculated by psychologists, the match rate reached 76%. The research proves that dreams are the continuation of real life, and dreams can provide a reference for psychological prediction and discovery of potential stressors.[10] In the latest research results in 2021, Maranci et al. research that adults will frown during normal sleep (mainly during REM sleep), but facial expressions with negative emotional significance are limited to patients with sleep disorders. Negative facial expressions for RBD patients can be used as a direct way to obtain dream emotions.[11]

1.2 Related artworks of sleep EEG visualization

In artworks of EEG visualization, emotion features are often mapped to visual elements and graphic characteristics. For instance, the more tensive emotions extracted from the electroencephalogram, the more concentratedly figures will distribute and the thicker brush strokes will present. On the contrary, meditation state exhibits scattered figures and light strokes. Daria Migotina et al. corresponded sleep EEG data with the shape, color, and size of strokes to form an abstract painting of EEG signals (Figure 1).[12] However, data processing details and perceptual explanation of the mapping rules were weakly explained. Q.Li generated a dynamic artwork using the sleep EEG data and other physiological electrical signals like horizontal electrooculogram(EOG) and chin electromyography(EMG), which controls the colors and moving velocity of lines.[13] In Li's thesis, "emptiness", rhythm, and spirit through brushstrokes" were interpreted according to Yijing and Taoism, endowing the artwork with the aesthetics of eastern philosophy.

2 EXPERIMENT AND EMOTION ANALYSIS

2.1 User Experiment

A total of 11 subjects were invited to this experiment, 5 males and 6 females respectively, aging from 20 to 30 years old. Subjects were instructed to sleep for about 8 hours all night.

The device used for monitoring subjects' EEG signals and other physiological signals is a polysomnography device. The device can automatically record the sleep stages, EEG signal, EOG signal, EMG signal, and other physiological indexes in the sleep. Figure 2 shows the wearing process of the device, including equipping EMG electrodes, EEG hat cap, and injecting electric cream.

After putting on the device, the subjects were required to fill out a PANAS-X questionnaire (Positive and Negative Affect Schedule - extended version) to provide an assessment of their emotional state before sleep. In this experiment, the PANAS-X questionnaire was used to quantitatively evaluate the positive-negative affect value of the subjects through 60 words describing different emotions.[14] The questionnaire has been translated and back-translated to prove that it is suitable for Chinese-culture individuals.[15] Figure 3 shows the user interface of a subject monitored by the polysomnography device, in which the internal algorithm of the PSG device is automatically divided into five suspected REM periods. The last rem period (purple circle) is considered by the instrument as a low confidence interval event (red on the upper confidence axis). Through monitoring the video, it was found that the subjects performed some activities after waking up in the morning. At the same time, there are four dreams reported after the subjects wake up, which is consistent with the results of automatic sleep staging by polysomnography. We extracted the parieto-occipital electrodes' EEG data of the first four (red circle) rem periods for visualization,

Figure 2: The preparation process of user experiment

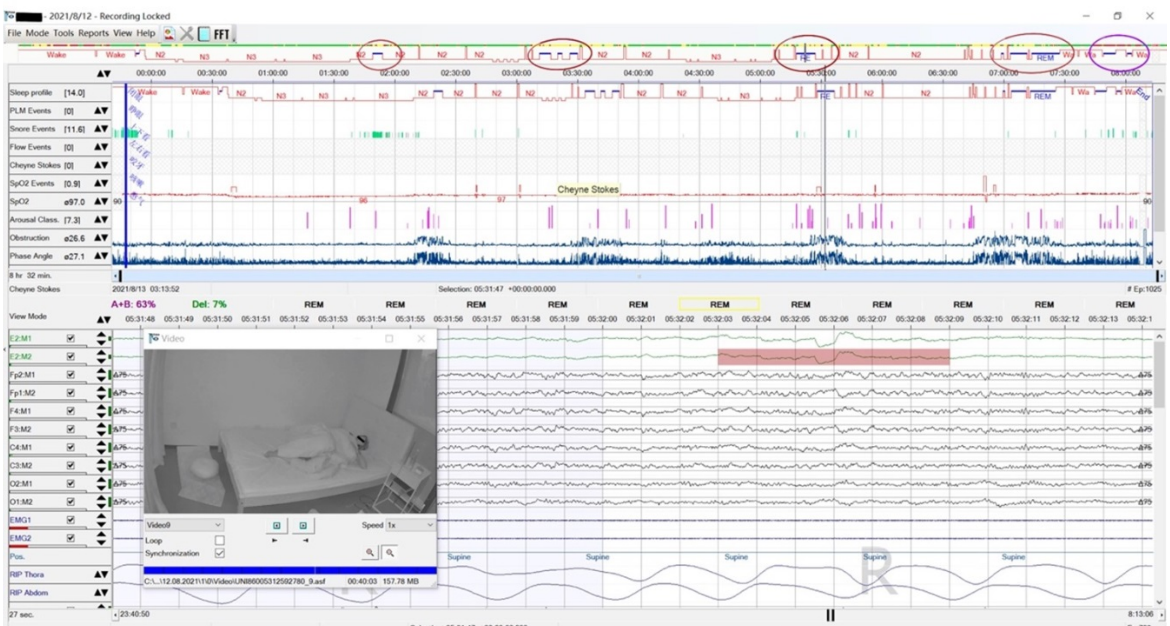

Figure 3: The UI interface showing process of user experiment data recorded from sleep monitoring device

and the parieto-occipital lobe area of the brain is considered to be highly related to the experience of dreaming.[16]

After waking up naturally the next morning, the subjects were instructed to fill out the PANAS-X questionnaire again based on their memory of experienced dreams. If the subject had multiple dreams at night, they needed to fill in multiple questionnaires. In addition, the subjects simply recorded the dream content in audio or text as required for subsequent feedback. Figure 4 shows the integrated process of the user experiment.

2.2 Emotion Assessment Results

Each word in the PANAS-X questionnaire has a score of 1-5 points. The general positive affect includes excited, interested, active, proud and so on. The general negative affect includes scared, nervous, guilty, upset, distressed, and so on. Calculation formulas for the two affects score are as follows:

$$Score_p = \frac{\sum_{i=1}^{n} affect_P(i)}{n}, \; n : subject\ number$$

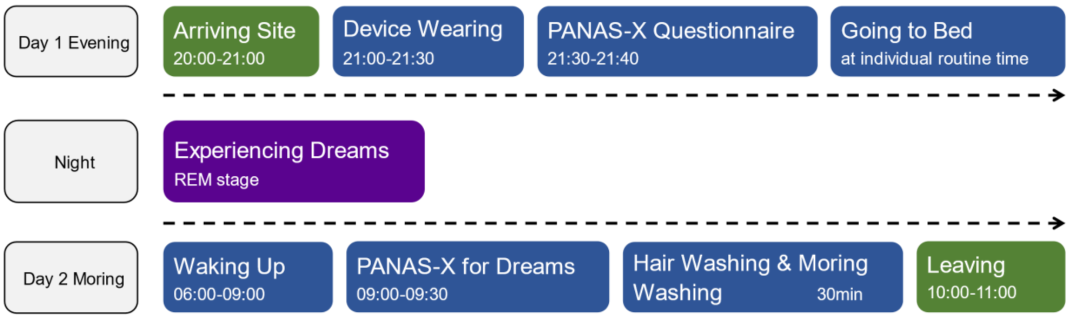

Figure 4: The process of user experiment

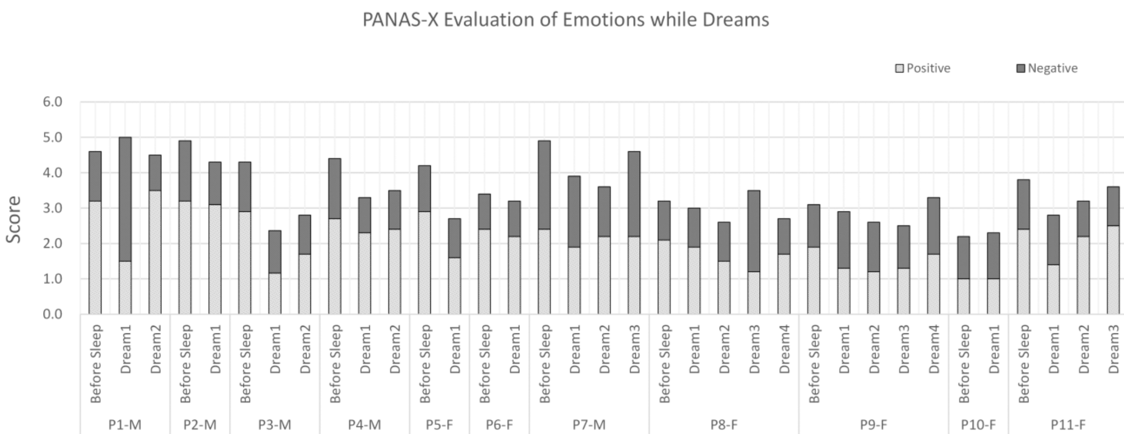

Figure 5: The analysis result of PANAS-X emotion evaluation

$$Score_N = \frac{\sum_{i=1}^{n} affect_N(i)}{n}, \; n: subject\ number$$

The calculation results are shown in Figure 5. As the statistic indicates, most of the subjects had a positive affect before sleep. There are dreams dominated by positive (P1 Dream2, P2 Dream1, P4 Dream1, etc.) or negative affect (P1 Dream1), and there are also dreams experiencing neutral affect (P3 Dream1, P7 Dream1, P8 Dream3, etc.) during sleep. The evaluation result is used as emotion labels of the dream to be input into the art generation algorithm to obtain an artistic work with a specific emotion style.

3 ARTWORK GENERATION

We expressed the visualization of dream emotions through the abstract art style of Chinese heavy-color ink and wash. The algorithm converted sleepers' EEG data during REM sleep when dreams always occur, into the artistic ink and wash paintings. According to the correspondence of colors and basic emotions proposed by Osvaldo et al.,[17] including anger, surprise, disgust, sadness, happiness, and fear, we matched the general tonal of paintings with the emotion category calculated by PANAS-X questionnaire. In terms of specific operations, we utilized the data of the entire frequency range of REM sleep extracted from several selected electrodes. Then we imported the data into TouchDesigner, an interactive visual programming software, and selected specific data channels to control the trajectory of the brush. For example, the size, position, border size, and transparency value of the brush changed dynamically in real-time following the selected EEG data. In the drawing process, the brush combined original EEG data, modulated by a low-frequency oscillator with uncertainty, and generated noise to enrich the variation of paintings. In addition, we are still improving the algorithm to generate a gradually vanishing dynamic effect to simulate the blurring stage of dreams happening in our brains.

The following figures (Figure 6, Figure 7, Figure 8, Figure 9, Figure 10) are some examples of dream-generated paintings and their corresponded emotion evaluation scores.

4 USER FEEDBACK

After the experiment, a return visit was made to each participant based on the dream images generated by the REM EEG to verify

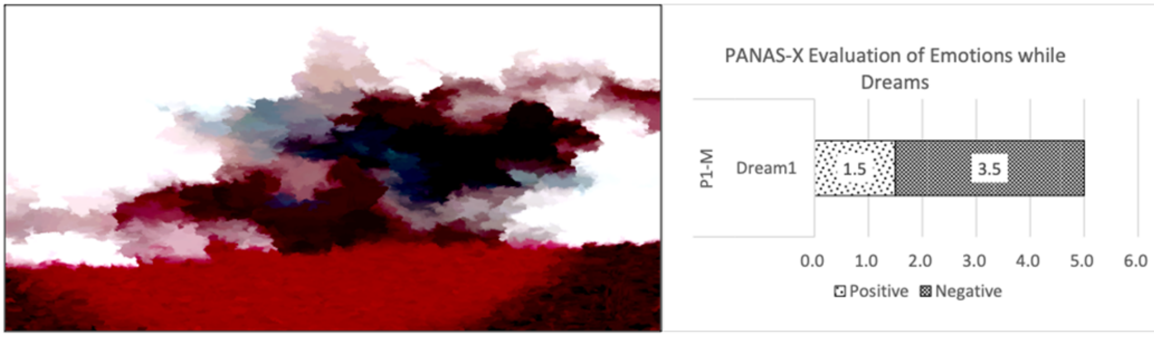

Figure 6: Artistic visualization of subject No.1's dream1. Obvious negative style; Dream emotion keyword: angry.

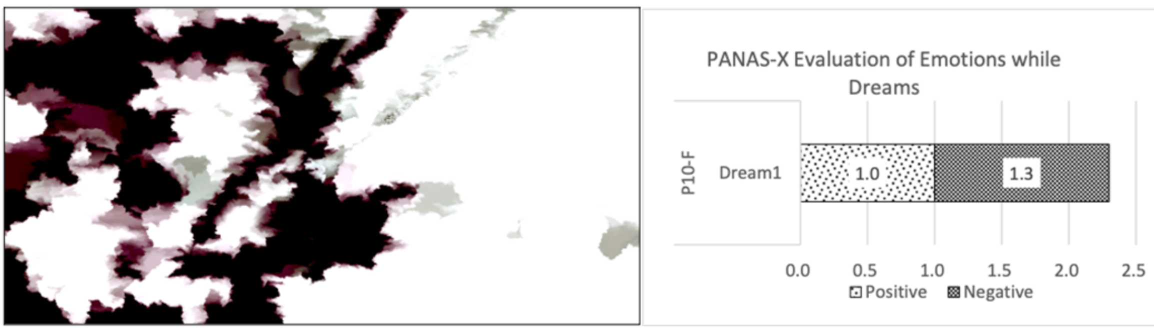

Figure 7: Artistic visualization of subject No.10's dream1. Slight negative style; Dream emotion keyword: busy.

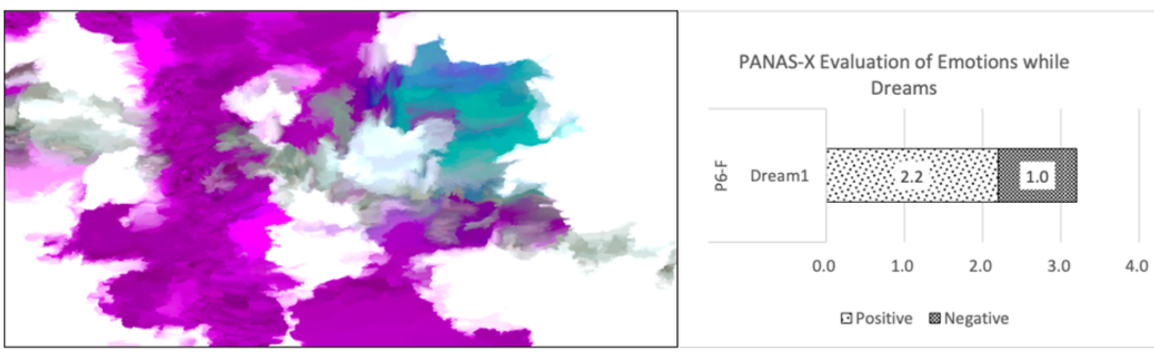

Figure 8: Artistic visualization of subject No.6's dream1. Obvious positive style; Dream emotion keyword: love.

Figure 9: Artistic visualization of subject No.5's dream1. Slight positive style; Dream emotion keyword: love.

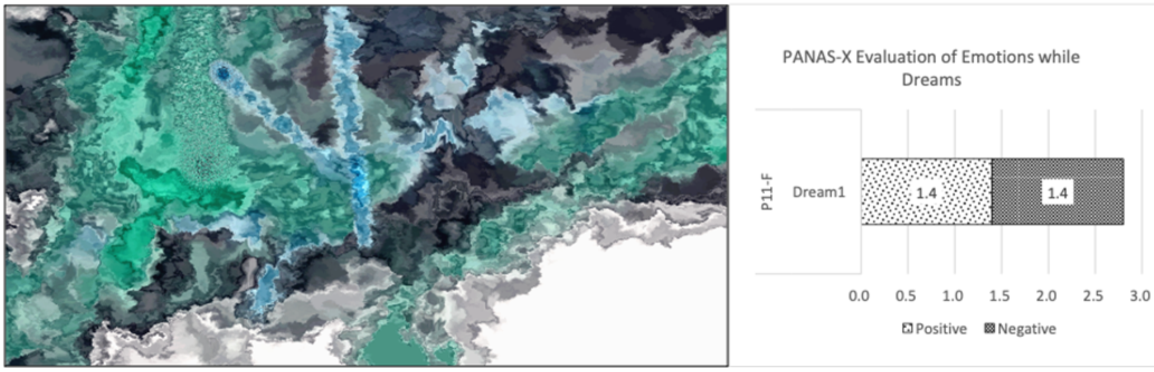

Figure 10: Artistic visualization of subject No.11's dream1.Neutral style; Dream emotion keyword: relieved.

Table 1: Comparison of PANAS-X Results of Participants' Dream Emotions and Feedback Emotions

ID	Stage	Positive Emotion	Negative Emotion	Fear	Hostility	Guilt	Sadness	Joviality	Self-ssurance	Attentive-ness
1	Dream	1.50	3.50	3.33	3.67	2.50	2.20	1.00	1.50	2.00
	Feedback	1.60	2.70	2.83	2.00	1.83	2.80	1.50	1.67	1.75
2	Dream	3.10	1.20	1.83	1.17	1.17	1.60	2.74	2.33	5.00
	Feedback	3.60	1.60	1.67	1.67	1.33	2.00	4.00	3.50	2.75
3	Dream	2.90	1.50	1.83	1.00	1.17	2.00	3.00	1.67	2.25
	Feedback	2.30	1.00	1.00	1.00	1.00	1.00	2.88	1.67	2.25
4	Dream	2.30	1.00	1.00	1.00	1.00	1.00	2.88	1.67	2.25
	Feedback	2.50	1.00	1.00	1.00	1.00	1.00	3.63	1.83	2.00
5	Dream	1.60	1.10	1.67	1.00	1.00	1.00	1.25	1.67	1.75
	Feedback	1.40	1.50	1.67	1.17	1.00	1.40	1.13	1.33	1.50
6	Dream	2.20	1.00	1.00	1.00	1.00	1.00	2.88	1.33	2.25
	Feedback	2.20	2.20	2.17	2.00	1.67	2.60	2.38	2.17	1.50
7	Dream	1.90	2.00	2.33	1.00	2.33	1.60	1.50	1.50	2.50
	Feedback	1.90	2.00	2.33	1.83	1.50	2.20	1.63	1.67	2.25
8	Dream	1.90	1.10	1.67	1.00	1.00	1.00	2.25	1.67	2.00
	Feedback	2.00	1.30	1.50	1.17	1.00	1.20	2.50	1.83	2.50
9	Dream	1.30	1.60	1.67	1.17	1.00	1.00	1.00	1.00	2.00
	Feedback	1.90	2.10	1.83	2.67	1.50	2.00	1.50	1.33	3.00
10	Dream	1.00	1.20	1.50	1.00	1.00	1.40	1.00	1.00	1.00
	Feedback	1.00	1.00	1.00	1.00	1.00	2.20	1.13	1.00	1.00
11	Dream	1.40	1.40	2.00	1.17	1.00	1.60	1.00	1.33	2.25
	Feedback	2.40	1.20	1.67	1.33	1.17	1.60	3.00	1.67	2.25

the validity. Since the number of dreams of each subject is not consistent per night, the first valid dreams of the subjects are uniformly selected in the questionnaire. An effective dream here means that the participant can recall the emotions and general content of the dream and fill out the PANAS questionnaire. Each participant will see a picture and fill out the questionnaire according to the picture. In order to ensure that the subjects are consistent in the judgment of the emotions shown in the screen, the PANAS-X scale was used again to investigate the emotional arousal of the subjects after seeing the screen to verify the effectiveness of the generated screen. The subject's emotional arousal to the generated images was also calculated according to the PANAS-X emotional scale scoring standard. The result is as follows (Table 1).

In order to verify the effectiveness of the image generation algorithm, the positive and negative emotional values of the subjects' sleep emotions and the positive and negative emotional values in the filled-in feedback form were set as a two-dimensional emotion vector. For example, subject 1's dream emotion vector is $[\begin{matrix}1.5\\3.5\end{matrix}]$, while the feedback emotion vector is $[\begin{matrix}1.6\\2.7\end{matrix}]$.Calculating the similarity of two vectors can be measured by cosine similarity. By calculating the cosine similarity between the two emotion vectors, we can measure how robust the relationship between the emotions in the participants' dreams and the emotions that generate the true reaction of the picture is. The results is shown as below (Figure 11).

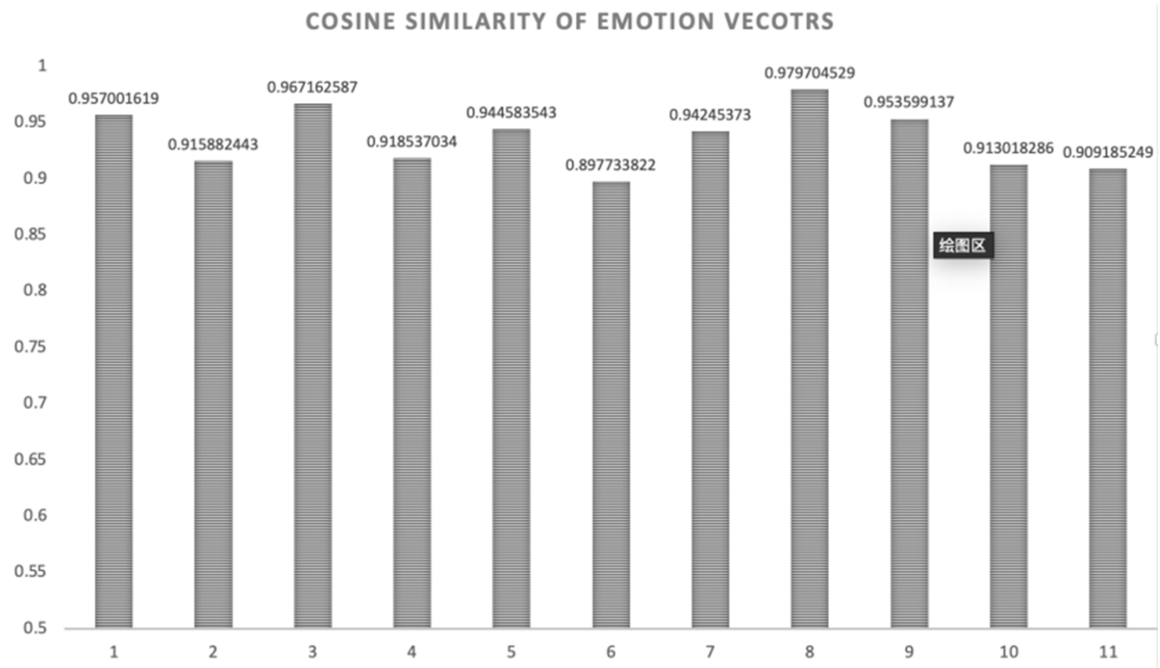

Figure 11: Cosine Similarity of Emotion Vecotrs

The result visually shows the similarity between the two emotion vectors of each subject. It can be found that, except for subject No. 6, the similarity between the two emotion vectors of the other subjects, or the emotions in their dreams and the real emotions evoked by the picture, exceeds 90%, and even reaches about 97% at the highest. Participants also had a similarity of 89%(0.897733822187143). Therefore, under this evaluation standard, we can consider the image generation algorithm to be effective.

5 CONCLUSION & LIMITATION

This research has summarized the main schools of dream research and related work on dream visualization and proposed a novel method of artistic dream visual expression based on objective data and subjective evaluation. In this study, a polysomnography EEG monitoring equipment was used to record EEG and physiological indicators during sleep, and an 11-subject experiment was conducted to obtain authentic EEG data and emotion self-evaluation. Based on EEG data of REM stage and human subjective emotions, we carried out artistic data analysis and generated a series of abstract artworks. Through theoretical research, EEG experiments and artistic creation practice, this research summarizes a new method for artistic analysis of EEG data and emotional evaluation and generating abstract dream visualization images.

However, this study also has certain limitations. If there are fewer subjects, the effectiveness of the algorithm cannot be verified to a greater extent. This is because the study of human sleep, especially the study of dreams, requires a specific experimental environment, and it is difficult to recruit participants and arrange the experimental time. In the future, we hope to recruit more subjects to further optimize and perfect the algorithm. Another problem is reflected in the efficiency of the algorithm. It is actually very time-consuming to generate each participant's dream image. Due to the high sampling rate of the experimental equipment, the preprocessing of the collected EEG data also takes a lot of time. In the future, we also hope to further improve the algorithm, improve the efficiency of image generation, and even achieve the result of real-time display of emotional images during sleep. Hope that our work in the future can overcome these difficulties and further explore the possibility of visualization of dreams.

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REFERENCES

[1] FREUD S. Observations on the Theory and Practice of Dream Interpretation [J]. Int Z Psychoanal, 1923, 9(1): 1-11.
[2] JUNG C. Memories, Dreams, Reflections - Jung,Cg [J]. Economist, 1963, 208(3): 268-.
[3] ASERINSKY E, KLEITMAN N. Regularly Occurring Periods of Eye Motility, and Concomitant Phenomena, during Sleep [J]. Science, 1953, 118(3062): 273-4.
[4] ROFFWARG H P, MUZIO J N, DEMENT W C. Ontogenetic Development of Human Sleep-Dream Cycle [J]. Science, 1966, 152(3722): 604-+.
[5] Alarcao, S. M., & Fonseca, M. J. (2017). Emotions recognition using EEG signals: A survey. IEEE Transactions on Affective Computing, 10(3), 374-393.
[6] YU M, ZHANG D, ZHANG G, *et al.* A review of EEG features for emotion recognition [J]. SCIENTIA SINICA Informationis, 2019, 49(9): 1097-118.
[7] FOSSE R, STICKGOLD R, HOBSON J A. The mind in REM sleep: Reports of emotional experience [J]. Sleep, 2001, 24(8): 947-55.
[8] L. P. Marquis, T. Paquette, C. Blanchette-Carriere, G. Dumel, and T. Nielsen, "REM Sleep Theta Changes in Frequent Nightmare Recallers," Sleep, vol. 40, no. 9, Sep 1 2017, doi: 10.1093/sleep/zsx110.
[9] SIKKA P, REVONSUO A, NOREIKA V, *et al.* EEG Frontal Alpha Asymmetry and Dream Affect: Alpha Oscillations over the Right Frontal Cortex during REM Sleep and Presleep Wakefulness Predict Anger in REM Sleep Dreams [J]. J Neurosci, 2019, 39(24): 4775-84.

[10] FOGLI A, MARIA AIELLO L, QUERCIA D. Our dreams, our selves: automatic analysis of dream reports [J]. R Soc Open Sci, 2020, 7(8): 192080.
[11] J. B. Maranci, A. Aussel, M. Vidailhet, and I. Arnulf, "Grumpy face during adult sleep: A clue to negative emotion during sleep?," J Sleep Res, p. e13369, Apr 29 2021, doi: 10.1111/jsr.13369.
[12] Migotina, D., Isidoro, C., & Rosa, A. Daria Migotina Paper: BRAIN ART: ABSTRACT VISUALIZATION OF SLEEPING BRAIN.
[13] Li, Q. (2020). Taoist Data Visualization. In Embodying Data (pp. 139-170). Springer, Singapore.
[14] Watson, D., & Clark, L. A. (1999). The PANAS-X: Manual for the positive and negative affect schedule-expanded form.
[15] Guo, M. Z., & Gan, Y. Q. (2010). Reliability and validity of the Chinese version of positive and negative affect schedule-expanded in 660 college students. Chinese Mental Health Journal, 24(7), 524-528.
[16] Siclari, F., Baird, B., Perogamvros, L., Bernardi, G., LaRocque, J. J., Riedner, B., ... & Tononi, G. (2017). The neural correlates of dreaming. Nature neuroscience, 20(6), 872-878.
[17] Da Pos, O., & Green-Armytage, P. (2007). Facial expressions, colours and basic emotions. Colour: design & creativity, 1(1), 2.