The EEG Oscillations and Psychology Propensities of Autonomous Sensory Meridian Response

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***Abstract*— Autonomous sensory meridian response is believed as a perceptual phenomenon to specific sensory stimuli. To explore the underlying mechanism and emotional effect, the EEG under video and audio triggers of autonomous sensory meridian response was analyzed. The differential entropy and power spectral density by Burg method on δ, θ, α, β, γ and high γ frequencies were employed as quantitative features. The results indicate that the modulation of autonomous sensory meridian response on brain activities is broadband. Video trigger owns better performance of autonomous sensory meridian response than other triggers. Moreover, the results also reveal that autonomous sensory meridian response has a close relationship with neuroticism and its three subdimensions, anxiety, self-consciousness and vulnerability, with the scores of self-rating depression scale, but without emotions, happiness, sadness, or fear. This suggests that the responders of autonomous sensory meridian response may have the tendencies of neuroticism and depressive disorder.**

***Index Terms*— EEG, brain activity, ASMR, personality.**

I. Introduction

AUTONOMOUS sensory meridian response (ASMR) is a complex sensory phenomenon. It includes a tingling, pleasant, warm or even static-like sensation on the scalp, back of the neck and body [1]. These sensory phenomena can last several minutes. The stimuli of ASMR typically involve repetitive auditory stimuli such as cutting, chewing, tapping noise and whisper, and/or viewing visual stimuli such as, repetitive actions, soft touching and some interpersonal stimuli [2]. As an autonomous response of brain, this phenomenon is observed in recent years and has not been well researched [3], but it is very common even in the daily life. A survey indicates that there is an approximately 15% undergraduate psychology students who demonstrated a substantial level of self-reported ASMR propensity [4]. ASMR is suggested to significantly increase the sleepiness [5] and sleep quality [6], and to decrease the state anxiety and attentional bias to a certain extent [7]. Therefore, many people watch ASMR videos or audios for relaxing, reducing stress and depression, restraining chronic pain, and promoting sleep [8], [9]. Despite this, currently, there is little known about ASMR's mechanisms.

The study about ASMR indicates that the subjective feeling of ASMR experience often manifests as calm, relaxation [10] and pleasure [11], etc. Barratt and Poerio [10], [12] report that there is a positive experience for most individuals during ASMR. Some individuals experienced ASMR report that they feel tactile sensation [1]. Poerio measured the sensory sensitivity between ASMR and non-ASMR responders and reveal that ASMR responders have greater interoceptive sensitivity and bodily awareness. ASMR is believed to be in relation to individual differences in environmental sensitivity, interoception, and emotional appraisal processes [13]. Gillmeister reports that ASMR-responders have more frequent and intense vicarious touch experiences [14]. That means there is a higher incidence of mirror-touch synaesthesia and positive reactions to social touch in ASMR experiencers. Therefore, previous study considered ASMR as a form of touch and/or emotional synaesthesia [1], because ASMR's trigger can automatically elicit another experience, such as tactile, tingling sensation and/or calm [15], [16]. Based on this hypothesis, the synaesthesia, misophonia-like hypothesis mechanism, was used to be popular [17]. However, Roberts performed a mixed-examination between ASMR and frisson scores, and the results do not support the correlation between synesthesia and ASMR [4]. Moreover, ASMR is thought to promote activation in regions both reward and emotional arousal [18]. The study by Keizer based on sensory suggestibility scale suggests that the participants who experience ASMR are

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TABLE I
THE SELF-ASSESSMENT ASMR QUESTIONNAIRE

No.	Questions	Answer (scores)		
1	Have you experienced ASMR previously?	Yes (10)	Not Sure (5)	No (0)
2	Can these words, tingling, pleasant, warm or static-like sensation, strongly describe your previous ASMR reflection?	Yes (10)	Not Sure (5)	No (0)
3	After hearing the auditory stimulus, do you strongly feel tingling, pleasant, warm or static-like sensation on your brain or your body?	Yes (10)	Not Sure (5)	No (0)

more prone to experience illusory sensory [19]. This indicates that ASMR is associated not only to cognitive traits such as imagery ability but also to how individuals physically experience sensory. Morales used the emotion regulation questionnaire to assess individual differences in the use of cognitive reappraisal and expressive suppression, and reveals that ASMR owns individual differences and has remarkable consequences in affective/emotional dimensions and general well-being [20]. McErlean studied ASMR by the questionnaires of flow, absorption and mindfulness, and suggests that the ability to get deeply immersed with the current experience accompanied by loss of reflective awareness may be an important factor contributing to the experience of ASMR [21]. Another mechanism explanation of ASMR indicates that the relaxation effect of ASMR may have similar mechanisms with reducing attention [1]. Studies by functional magnetic resonance imaging (fMRI) indicate that the default mode network of individuals with ASMR experience owns less functional connectivity than the one without ASMR experience [22]. Smith explored the functional connectivity based on fMRI during AMSR, and reveals that the dorsal attention network is positively correlated with ASMR trigger, indicating an underlying involvement of the atypical attentional processing during ASMR [2]. The study based on electroencephalography (EEG) indicates that the auditory ASMR trigger can elicit the increasement of alpha (mu) and gamma wave activity during the self-reported ASMR. This proves that ASMR includes both attentional and sensorimotor characteristics [23], and then to increase the brain activities related to sensation, movement, and attention [24]. To conclude, ASMR is a real psychophysiological phenomenon and may be associated with some psychological constructs and however, the mechanism of ASMR is still obscure. More supports of quantitative data and phenomenon are urgently needed.

Many modalities have been applied to observe the activities of brain, such as EEG [25], magnetoencephalography (MEG) [26] and fMRI [27]. EEG is one of the most common non-invasion and high time-resolution ways to measure brain activity [28]. EEG can be divided into δ (0.5 Hz - 4 Hz), θ (4 Hz - 8 Hz), α (8 Hz - 13 Hz), β (13 Hz - 30 Hz), γ (30 Hz - 49 Hz) and high γ (51 Hz - 99 Hz) frequencies [29]. These frequencies can be extracted by Finite-Impulse-Response (FIR) filter, which is a common filter to extract EEG sub-band [30], [31]. Among these frequencies, δ and θ activities are suggested to related to mental fatigue and sleep [32]. α frequencies mostly appear on the occipital and parietal lobes and are attenuated with eye opening. It is related to cognitive tasks and attention [33]. β frequencies is believed to have relationship with concentration, logical thinking, alertness or anxiety [33]. γ and high γ are considered to be important rhythms for brain signal transduction and are involved in cognitive processing. They usually appear on the somatosensory cortex, and are related to the excited or hyper state and cross-modal perceptual processing. Thus the sub-band of EEG can be applied to explore the cognitive processing of ASMR. Power spectral density (PSD) and differential entropy (DE) have been widely applied as features to study and classify emotion-related EEG in the previous studies [34], [35]. PSD can be estimated by many methods, such as Burg method, Yule Walker method, Eigen method, and multiple signal classification method. Previous study indicates that Burg method is more precise for PSD calculation of EEG [36]. It is hypothesis that ASMR is a kind of emotion response to triggers with individual difference. Therefore, in this study, we analysed PSD by Burg method and DE of EEG under multi visual and/or auditory triggers with the aims to disclose the EEG reflection of ASMR, to explore the association between ASMR and emotion, and to find ASMR's personality features. It is also hopefully to revealing the underlying mechanism of ASMR.

II. MATERIALS AND METHODS

A. Participants

The study included 34 participants (19 males and 15 females, MAge = 21.73 years, SDAge = 4.28 years) who did not suffer from any injury, diseased vision or diseases in central nervous. These participants were selected from over one hundred volunteers by a self-assessment ASMR questionnaire. The questionnaire is illustrated in Table I. The volunteers answered the questionnaire after hearing an ASMR auditory trigger which refers to a sand cutting sound. The volunteers which scored more than 25 or lower than 10 could be selected as participants. After questionnaire, 20 participants with 30 scores as experimental group and 14 participants with scores lower than 10 as control group were involved in the experiments after signing informed consent for inclusion. This study was conducted by the Declaration of Helsinki, and the protocol of experiment was approved by the ethical review board of Shenzhen Technology University.

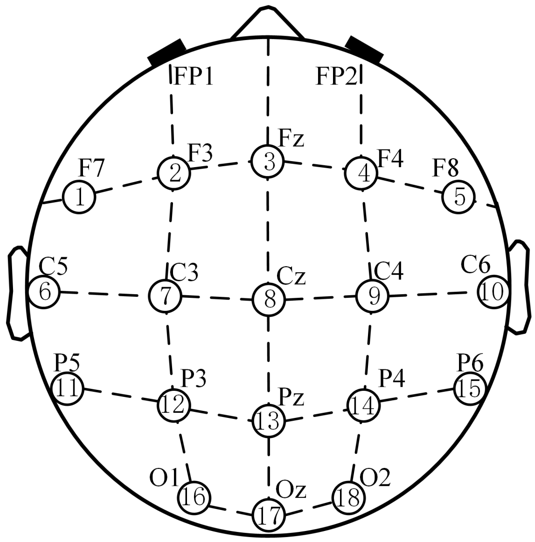

Fig. 1. The electrode distribution.

B. Recordings and Questionnaire

EEG was collected by a g.USBamp system from eighteen active Ag/AgCl electrodes in accordance with the 10-20 electrode location system. During EEG collection, the left earlobe and frontal position (FPz) were used as the reference and ground, respectively. The electrode distribution is shown in Fig. 1. The impedances of all the electrodes were kept below 30 kΩ. The sampling rate of EEG was 500 Hz. Before experiments, the revised neuroticism extraversion openness personality inventory (NEO-PI-R), which was proposed by Costa and McCrae in 1992 [37] was applied to evaluate the participants' personality on five dimensions: openness, conscientiousness, extraversion, agreeableness and neuroticism. The dimensions and thirty sub-dimensions are illustrated in Table II. This questionnaire comprises 240 questions and can be answered using a 5-point Likert scale. 1 denotes strong disagreement with the question and 5 indicates strong agreement with the question. Moreover, the self-rating depression scale (SDS) and self-rating anxiety scale (SAS), which were proposed by Zung in 1965 and in 1971 [38], were used to evaluate the mental state of participants. SDS and SAS are both consist of 20 questions and can be answered using a 4-point Likert scale. The scores distribution is similar with NEO-PI-R. The scores of each dimension and sub-dimension in NEO-PI-R, SDS and SAS had been calculated after questionnaires.

C. The Experimental Procedure

The participants sat comfortably in an armchair in the front of a computer screen with about 0.6 meters away in a dark laboratory after NEO-PI-R, SDS and SAS surveys. They were asked to focus on the stimuli located on the screen centre and to decrease the brain and body movements during experiments, with the aim to reduce artefact interference. EEG was recorded under four experimental conditions for comparison. In the video condition (VC), a video which refers to the audiovisual stimuli of continuous and soft sand cutting movement was displayed on the computer screen. In the audio condition (AC), the stimulus was only the audio stimulus of VC. In the noise condition (NC), the stimulus was a pre-generated Gaussian whitenoise audio. In the rest condition (RC), there was no additional audio and/or visual stimuli. The length and intensity of all the audio stimuli were consistent on all the conditions. During experiments, a crosshair lasted for 2 seconds was firstly to appear on the centre of the computer screen. Then, the four conditions appeared randomly. The durations of the four conditions were forty seconds. After one trial, there was one minute for participants to rest and adjust. Each condition repeated twice on the same participants. The paradigms of the four conditions were controlled by psychophysics toolbox [39] based on MATLAB (MathWorks, USA). After experiment, the question 3 of the self-assessment ASMR questionnaire in Table I was applied on the participants for self-evaluating the experience of ASMR under VC and AC conditions. Trials with 0 score in the experimental group and with 10 scores in the control group would be excluded from further analysis. Moreover, EEG had been visual checked. The trials with high amplitude artefacts were also been discarded. After checking above, 15 trials were excluded.

D. Public Dataset

The publically available emotion dataset, SEED IV, was collected for evaluating the correlation between emotion and ASMR. This public dataset included 15 participants and recorded EEG evoked by film clips, which can induce happiness, sadness, fear or neutral emotions. For each participant, 3 sessions were performed on different days, and each session contained 24 trials. EEG was collected with the 62-channel ESI NeuroScan system at sampling rate of 1000 Hz. This dataset is detailed in [34].

E. Analysis

The trials from the same condition were extracted and averaged from EEG flow. Afterwards, EEG were divided into δ, θ, α, β, γ and high γ frequencies by FIR filter. Then all the activities above were downsampled to 200 Hz and detrended. PSD by burg method and DE were applied on every frequency band to study ASMR's EEG features after segmenting with 0.5 s rectangular window without overlap. To evaluate the differences between different conditions, PSD, DE, the scores of NEO-PI-R's dimensions and its sub-dimensions and the scores of SDS and SAS were analyzed by statistical methods. According the hypothesis testing method, the data were firstly subjected to the Lilliefors test to determine whether they were normally distributed. If they obeyed the normal distribution, one-way analysis of variance (ANOVA) was applied to evaluate the differences between data. Otherwise, the Mann-Whitney test or Kruskal-Wallis test was employed.

III. Results

A. ASMR's Feature Distribution

The results of Lilliefors test indicated that DE on the four conditions obeyed the normal distribution, and PSD on the four conditions did not obeyed the normal distribution. Therefore, ANOVA and Mann-Whitney test were applied to study the

TABLE II
THE NEO-PI-R'S DIMENSION

Neuroticism (N)	Extraversion (E)	Openness (O)	Agreeableness (A)	Conscientiousness (C)
Anxiety (N1)	Warmth (E1)	Fantasy (O1)	Trust (A1)	Competence (C1)
Angry hostility (N2)	Gregariousness (E2)	Aesthetics (O2)	Straightforwardness (A2)	Order (C2)
Depression (N3)	Assertiveness (E3)	Feelings (O3)	Altruism (A3)	Dutifulness (C3)
Self-consciousness (N4)	Activity (E4)	Actions (O4)	Compliance (A4)	Achievement striving (C4)
Impulsiveness (N5)	Excitement seeking (E5)	Ideas (O5)	Modest (A5)	Self-discipline (C5)
Vulnerability (N6)	Positive emotions (E6)	Values (O6)	tender-mindedness (A6)	Deliberation (C6)

difference on DE and PSD between the experimental and control groups, respectively. Factor was "group" (experiment vs control). The results indicated that there were significant differences between the two groups on PSD (VC: $Z = 28.2$, $P < 0.001$; AC: $Z = 15.9$, $P < 0.001$; NC: $Z = 20.3$, $P < 0.001$) and DE (VC: $F(1, 2915) = 1267.8$, $P < 0.001$, partial $\eta^2 = 0.397$; AC: $F(1, 2915) = 487.2$, $P < 0.001$, partial $\eta^2 = 0.207$; NC: $F(1, 2915) = 559.7$, $P < 0.001$, partial $\eta^2 = 0.238$) on VC, AC and NC conditions. Therefore, the experimental group should have a stronger ASMR response to the video and audio triggers than the control group.

To evaluate the difference among conditions, ANOVA was employed on DE of the experimental group. The factors were "condition" (VC, AC, NC and RC), "frequency" (δ, θ, α, β, γ and high γ) and "electrodes" (from 1 to 18). Bonferroni correction was used as the post-hoc test. Significant differences were found on "condition" ($F(3, 16845) = 205.98$, $P < 0.001$, partial $\eta^2 = 0.137$), "frequency" ($F(5, 28075) = 385.58$, $P < 0.001$, partial $\eta^2 = 0.331$) and "electrodes" ($F(17, 95455) = 198.25$, $P < 0.001$, partial $\eta^2 = 0.464$). Moreover, there were interaction effects between "frequency" and "condition" ($F(15, 84225) = 10.94$, $P < 0.001$, partial $\eta^2 = 0.04$) and between "frequency" and "electrodes" ($F(85, 477275) = 3.35$, $P < 0.001$, partial $\eta^2 = 0.068$). The interaction results implied that the four conditions distribute differently in frequency, but not differently on electrodes. The post-hoc results are displayed in Supplementary 1. To study the frequency distribution evoked by ASMR, ANOVA and Kruskal-Wallis test were employed on the experimental group's DE and PSD of δ, θ, α, β, γ and high γ frequencies, respectively. The factor of ANOVA was "condition" (VC, AC, NC and RC). The statistical results were shown in Table III. The post-hoc results by Bonferroni correction for ANOVA and Dunn-Bonferroni test for Kruskal-Wallis test were displayed in Fig. 2. These results revealed that to compare with RC, VC suppressed the values of DE and PSD on all the frequencies. AC and NC can reduce PSD and DE mainly on θ, α, β, γ frequencies. NC can suppress DE in high γ frequency, however, AC did not show that reduction. VC exhibited significantly lower DE on θ, α, β and high γ frequencies, and lower PSD on δ, θ, α, β and high γ frequencies than AC.

The DE features of the experimental group on all the frequencies were illustrated in Supplementary 2. Fig. 3 indicates the topographical views of the decibel difference of PSD between VC, AC or NC and RC. The topographical views indicate that to compare with RC, the power distributions of brain areas may be different on AC, NC or VC. To evaluate the differences among conditions on different brain areas, PSD and DE of δ, θ, α, β, γ and high γ frequencies on frontal area (F3, Fz, F4), left temporal area (F7, C5, P5), right temporal area (F8, C6, P6), central area (C3, Cz, C4), parietal area (P3, Pz, P4) and occipital area (O1, Oz, O2) in the experimental group were studied. The results of Lilliefors test revealed that PSD did not obey the normal distributions and DE obeyed the normal distributions. Therefore, ANOVA and Kruskal-Wallis test were employed. The factor for ANOVA was "condition" (VC, AC or NC and RC). The statistical results are shown in Table IV and Table V. The post-hoc results of DE by Bonferroni correction and PSD by Dunn-Bonferroni test are displayed in Fig. 4 and Fig. 5, respectively. These results reveal that to compare with RC, VC mainly affected the brain activities on θ, α, β and γ frequencies in the frontal area, on δ, θ, α and β frequencies in left temporal area, on θ, α and β frequencies in right temporal area, on δ, θ, α, β and γ frequencies in central area, on δ, θ, α, $\beta\gamma$ and high γ frequencies in parietal area and on δ, θ, α, β and γ frequencies in the occipital area. Moreover, AC suppressed DE of δ frequencies on the parietal and occipital areas, of θ frequencies on the six brain areas, of α frequencies on left and right temporal areas, and of γ frequencies on frontal, central and parietal areas. AC also exhibited PSD suppression in γ frequencies on frontal area. NC had similar DE suppressions with AC on brain areas. Thus, VC has wider brain responses than NC or AC in frequency and areas.

B. The Correlation Between ASMR and Emotion

To eliminate the effects of data acquisition's precision and magnification, we analyzed the ratio of DE or PSD between VC, AC or NC with RC on ASMR's data. Similarly, the PSD or DE on happiness, sadness, or fear emotion was compared with the one on neutral emotion. Lilliefors test results indicated that the ratio of DE and PSD on VC, AC, NC and three emotion conditions did not obeyed the normal distribution. Therefore, Kruskal-Wallis test was applied to evaluate the differences between ASMR and emotion. The factor was "conditions" (VC, AC, NC, happiness, sadness, and fear). The statistical results indicate that both PSD ($Z = 1147.52$, $P < 0.001$) and DE ($Z = 1704.06$, $P < 0.001$) had significant differences among the six conditions. The post-hoc results by Dunn-Bonferroni test were displayed in Fig. 6(a). This results indicated that VC, AC or NC has significant

TABLE III
THE STATISTICAL RESULT OF DE AND PSD ON DIFFERENT FREQUENCIES

f	DE	PSD
δ	$F(3, 2805) = 27.80$, $P < 0.001$, partial $\eta^2 = 0.114$	$Z = 25.68$, $P < 0.001$
θ	$F(3, 2805) = 62.85$, $P < 0.001$, partial $\eta^2 = 0.226$	$Z = 78.51$, $P < 0.001$
α	$F(3, 2805) = 143.99$, $P < 0.001$, partial $\eta^2 = 0.401$	$Z = 243.46$, $P < 0.001$
β	$F(3, 2805) = 30.20$, $P < 0.001$, partial $\eta^2 = 0.126$	$Z = 64.48$, $P < 0.001$
γ	$F(3, 2805) = 30.05$, $P < 0.001$, partial $\eta^2 = 0.126$	$Z = 41.57$, $P < 0.001$
high γ	$F(3, 2805) = 13.40$, $P < 0.001$, partial $\eta^2 = 0.059$	$Z = 16.66$, $P < 0.001$

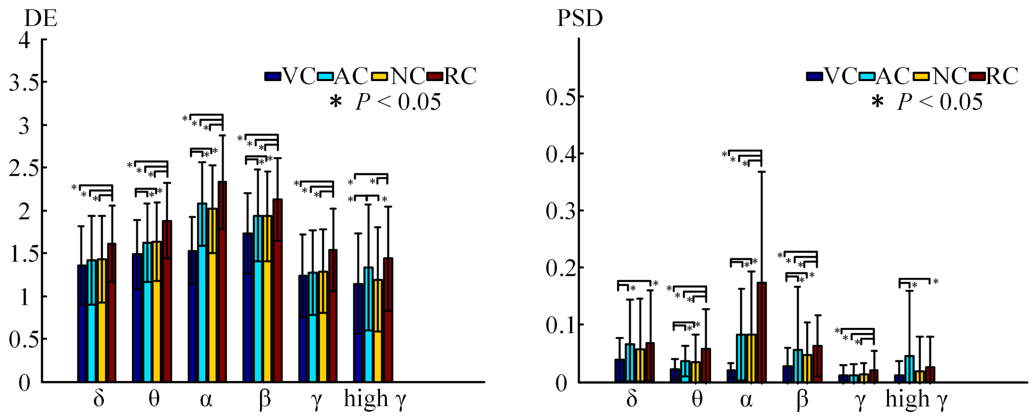

Fig. 2. The post-hoc results. (a) Bonferroni correction for ANOVA on DE; (b) Dunn-Bonferroni test for Kruskal-Wallis test on PSD.

TABLE IV
THE STATISTICAL RESULTS OF DE AND PSD ON FRONTAL, LEFT TEMPORAL AND RIGHT TEMPORAL AREAS

f	Feature	Frontal area	Left temporal area	Right temporal area
δ	DE[a]	$F = 1.73$, $P = 0.165$, $\eta^2 = 0.042$	$F = 3.07$, $P < 0.05$, $\eta^2 = 0.078$	$F = 2.28$ $P = 0.083$, $\eta^2 = 0.061$
	PSD	$Z = 7.48$, $P = 0.058$	$Z = 9.61$, $P < 0.05$	$Z = 8.64$, $P < 0.05$
θ	DE[a]	$F = 7.47$, $P < 0.001$, $\eta^2 = 0.160$	$F = 9.42$, $P < 0.001$, $\eta^2 = 0.206$	$F = 10.96$, $P < 0.001$, $\eta^2 = 0.237$
	PSD	$Z = 22.46$, $P < 0.001$	$Z = 22.62$, $P < 0.001$	$Z = 30.12$, $P < 0.001$
α	DE[a]	$F = 18.61$, $P < 0.001$, $\eta^2 = 0.321$	$F = 35.41$, $P < 0.001$, $\eta^2 = 0.494$	$F = 28.60$, $P < 0.001$, $\eta^2 = 0.447$
	PSD	$Z = 46.80$, $P < 0.001$	$Z = 61.34$ $P < 0.001$	$Z = 55.81$, $P < 0.001$
β	DE[a]	$F = 3.19$, $P < 0.05$, $\eta^2 = 0.077$	$F = 3.64$, $P < 0.05$, $\eta^2 = 0.093$	$F = 4.36$, $P < 0.01$, $\eta^2 = 0.110$
	PSD	$Z = 10.32$, $P < 0.05$	$Z = 12.84$, $P < 0.01$	$Z = 14.79$, $P < 0.01$
γ	DE[a]	$F = 5.71$, $P < 0.01$, $\eta^2 = 0.130$	$F = 1.23$, $P = 0.304$, $\eta^2 = 0.034$	$F = 2.70$, $P < 0.05$, $\eta^2 = 0.071$
	PSD	$Z = 14.90$, $P < 0.01$	$Z = 4.05$, $P = 0.256$	$Z = 8.91$, $P < 0.05$
high γ	DE[a]	$F = 2.59$, $P = 0.056$, $\eta^2 = 0.063$	$F = 0.79$, $P = 0.502$, $\eta^2 = 0.022$	$F = 1.15$, $P = 0.334$, $\eta^2 = 0.031$
	PSD	$Z = 9.59$, $P < 0.05$	$Z = 2.33$, $P = 0.508$	$Z = 2.98$, $P = 0.394$

a. The parameter of F-statistic is $F(3, 465)$. η^2 is partial η^2.

differences with the three emotions. Thus, this results imply that ASMR is not a kind of single emotion response to triggers.

C. ASMR's Personalized Propensity

The NEO-PI-R' five dimensions of the experimental and control groups were applied to study the personalized propensity of ASMR. Lilliefors test indicated that the five dimensions of the experimental and control groups obeyed the normal distributions. Therefore ANOVA was applied. The factor was "group" (experiment vs. control). The results indicated that there was only a significant different on neuroticism ($F(1, 33) = 7.23$, $P < 0.05$, partial $\eta^2 = 0.224$). The results are illustrated in Fig. 6(b). Therefore, the participants with strong ASMR experience may own greater neuroticism scores than the one without ASMR experience. To explore the main sub-dimensions that result in the difference above, the scores of neuroticism's sub-dimensions between "group" were also been studied. Lilliefors test indicated that the scores of the experimental and control groups on six sub-dimensions obeyed the normal distributions. Significant differences were found on anxiety ($F(1, 33) = 14.24$, $P < 0.05$, partial $\eta^2 = 0.363$), self-consciousness ($F(1, 33) = 5.02$, $P < 0.05$, partial $\eta^2 = 0.167$) and vulnerability ($F(1, 33) = 6.78$, $P < 0.05$, partial $\eta^2 = 0.213$). The results are illustrated in Fig. 6(c). Therefore, these sub-dimensions should be the main personality characteristics that result in ASMR response. Further, the participants with strong ASMR experience may be easy to be anxious and sensitive. Based on the scoring criteria of SDS and SAS, 4 participants suffered minor depressive disorders, and 2 participants suffered minor anxiety disorders in the experimental group. One of them suffered minor depressive disorder and anxiety disorder at the same time. The participant with depressive or anxiety disorders was not found in the control group. For the SDS and SAS

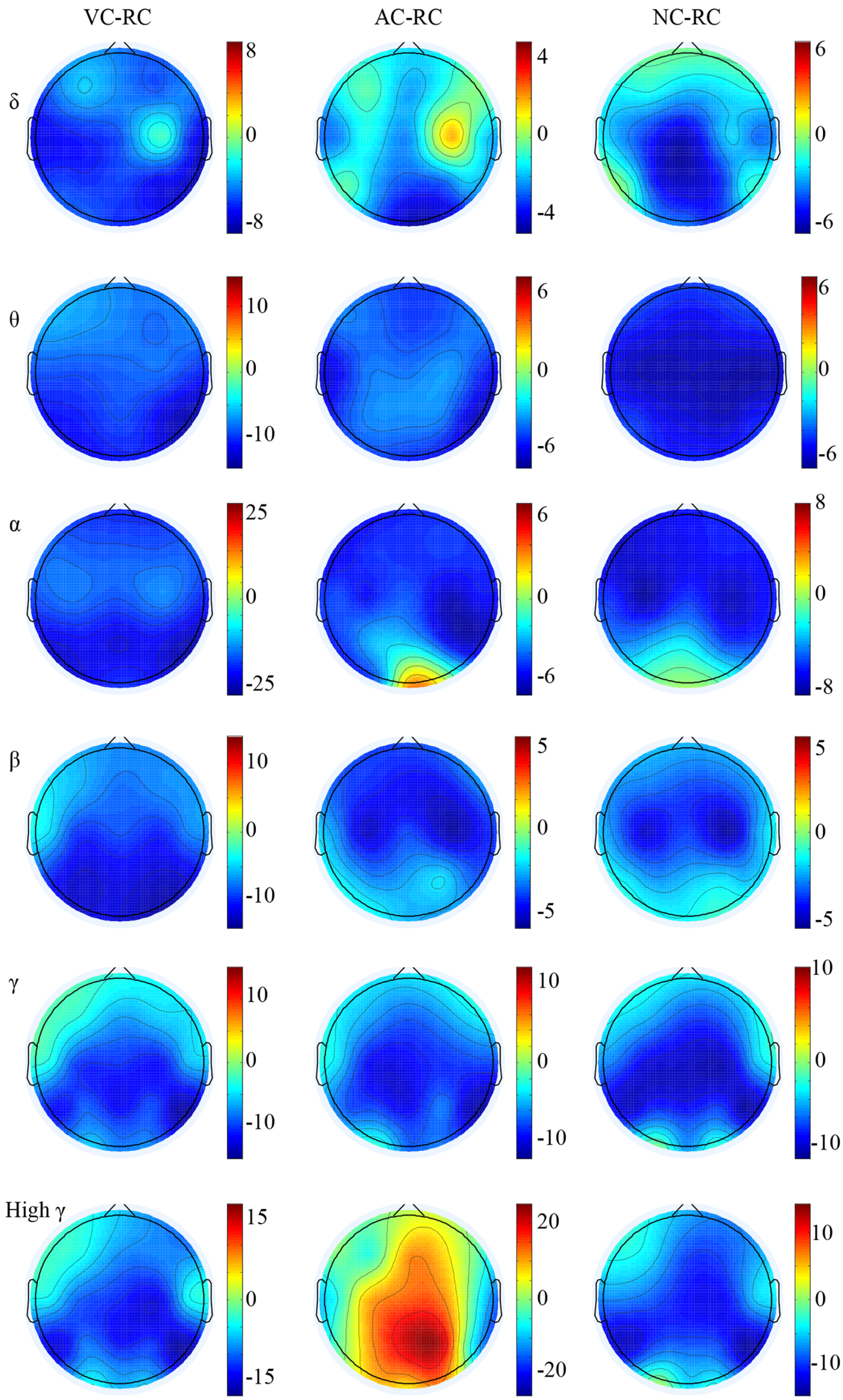

Fig. 3. The topographical views of the decibel difference of PSD between VC, AC or NC and RC.

scores from the experimental and control groups obeyed the normal distributions by Lilliefors test, ANOVA was applied to analyze the difference between "groups" (experiment vs control). The result indicated that significant difference was only found on SDS scores ($F(1, 33) = 7.63$, $P < 0.05$, partial $\eta^2 = 0.234$). The results are shown in Fig. 6(d). Moreover,

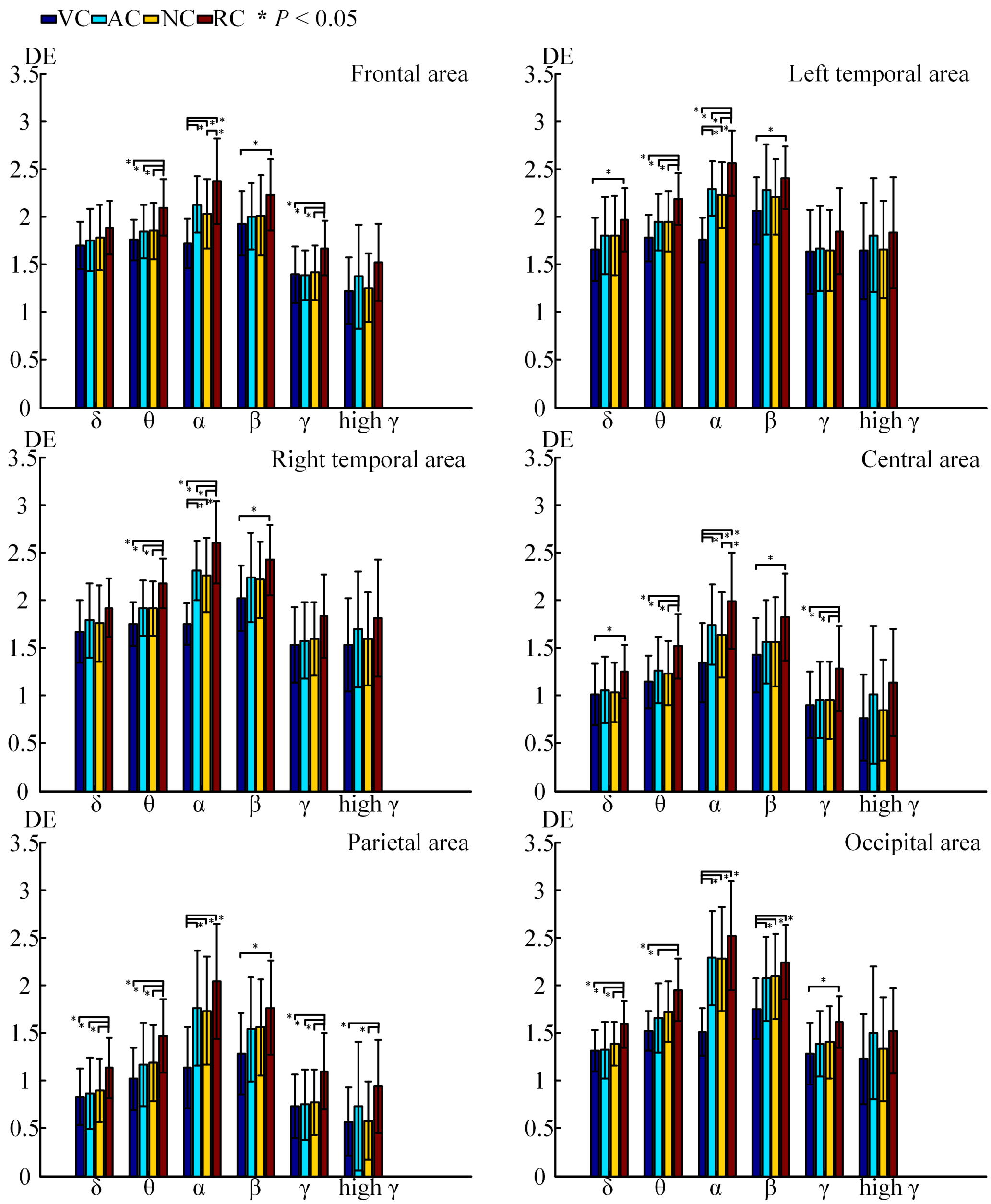

Fig. 4. The post-hoc results of DE on six brain areas.

to explore the relationship between depressive disorder or anxiety disorder and ASMR's personalized propensity, the Pearson correlation coefficient was applied to analyze the correlation between the three sub-dimensions of neuroticism and SDS or SAS scores after normalization. The results are illustrated in Table VI. This reveal that there is no significant correlation between the three sub-dimensions and SDS or SAS scores.

IV. Discussion

ASMR has been suggested to promote positive emotion, such as calmness and excitement and even beyond self-reported feelings of physiological measures, to reduce heart rate and increase skin conductance level in ASMR responders while watching ASMR videos [10]. Previous study also indicates that watching ASMR video can alleviate anxiety state in the participants who experienced ASMR [40]. These studies imply that there is an association between ASMR and emotion. In this study, the result revealed that to compare with RC, VC suppressed the values of PSD and DE on all the frequencies. AC can reduce PSD and DE mainly on θ, α, β, γ frequencies. Thus, the modulation of ASMR on brain activities is broadband. Similar broadband brain activities can also be found on the brain's emotion response [41], [42]. The θ frequency can decrease with the increasing positive valence [43], [44]. α frequency is proved to increase with the increasing positive emotional arousal [43]. γ wave can be affected by valence [45]. High γ frequencies is suggested to have a relationship with the cognitive control of emotions [46]. Therefore, ASMR may involve in increasing positive valence and decreasing positive emotional arousal. However, significant differences were found between ASMR

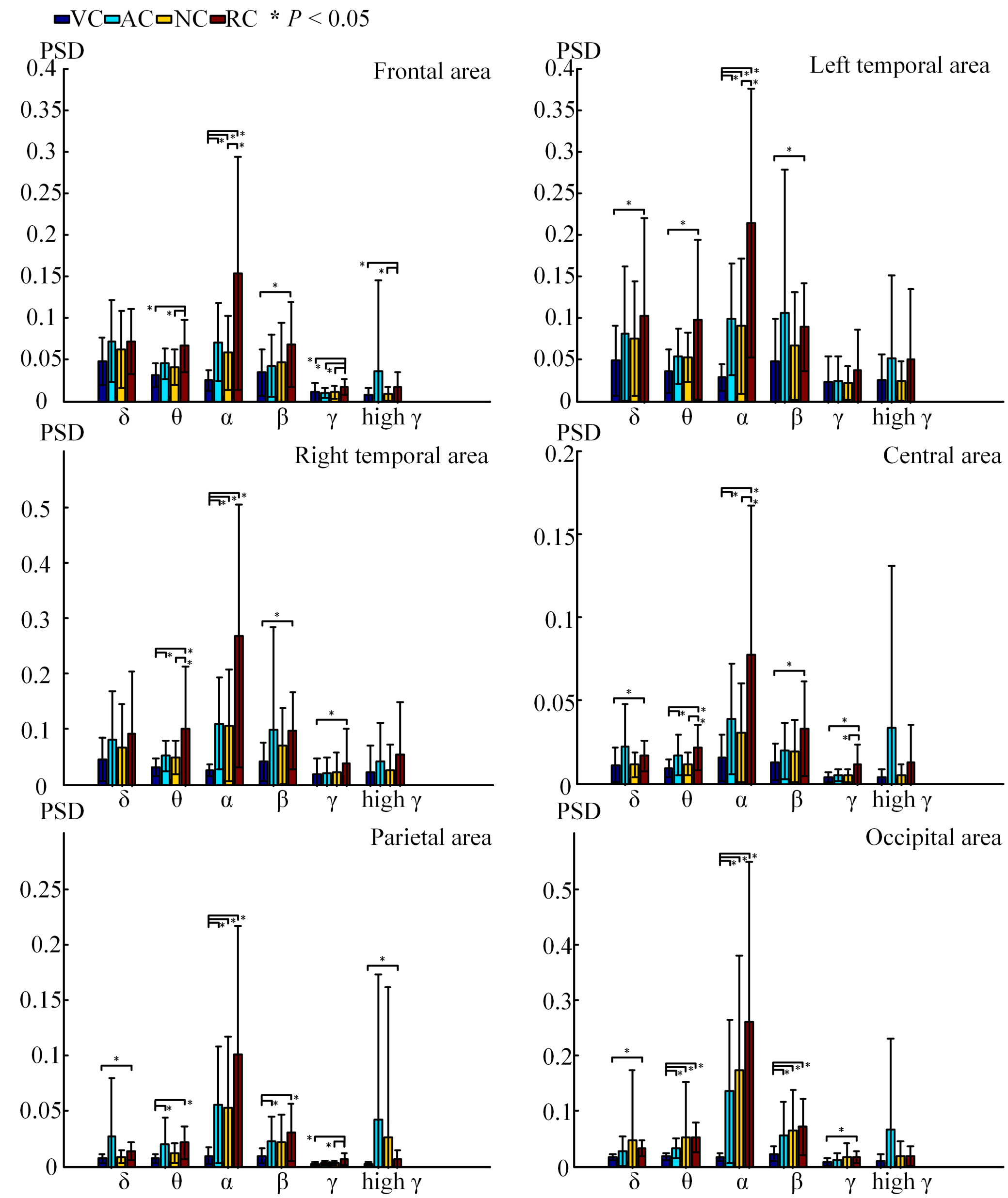

Fig. 5. The post-hoc results of PSD on six brain areas.

TABLE V
THE STATISTICAL RESULTS OF DE AND PSD ON CENTRAL, PARIETAL AND OCCIPITAL AREAS

f	Feature	Central area	Parietal area	Occipital area
δ	DE[a]	F= 3.44, P < 0.05, η^2 = 0.076	F= 5.06, P < 0.01, η^2 = 0.110	F= 6.32, P < 0.01, η^2 = 0.153
	PSD	Z = 12.36, P < 0.01	Z = 13.32, P < 0.01	Z = 16.80, P < 0.01
θ	DE[a]	F= 7.26, P < 0.001, η^2 = 0.148	F= 7.08, P < 0.001, η^2 = 0.147	F= 8.93, P < 0.001, η^2 = 0.203
	PSD	Z = 20.11, P < 0.001	Z = 22.01, P < 0.001	Z = 30.45, P < 0.001
α	DE[a]	F= 11.39, P < 0.001, η^2 = 0.215	F= 15.65, P < 0.001, η^2 = 0.276	F= 24.92, P < 0.001, η^2 = 0.416
	PSD	Z = 30.68, P < 0.001	Z = 44.00, P < 0.001	Z = 48.36, P < 0.001
β	DE[a]	F= 4.28, P < 0.01, η^2 = 0.095	F= 5.20, P < 0.01, η^2 = 0.114	F= 7.27, P < 0.001, η^2 = 0.176
	PSD	Z = 13.22, P < 0.01	Z = 20.15, P < 0.001	Z = 22.56, P < 0.001
γ	DE[a]	F= 5.58, P < 0.01, η^2 = 0.121	F= 6.78, P < 0.001, η^2 = 0.144	F= 4.29, P < 0.01, η^2 = 0.112
	PSD	Z = 12.58, P < 0.01	Z = 17.11, P < 0.01	Z = 16.55, P < 0.01
high γ	DE[a]	F= 2.28, P = 0.082 η^2 = 0.053	F= 3.38, P < 0.05, η^2 = 0.077	F= 1.50, P = 0.22, η^2 = 0.042
	PSD	Z = 6.42, P = 0.093	Z = 8.55, P < 0.05	Z = 4.93, P = 0.177

a. The parameter of F-statistic is $F(3, 465)$. η^2 is partial η^2.

and the emotions, happiness, sadness, or fear. Therefore, the study does not support the hypothesis that ASMR is a kind of a single emotion response to triggers. Thus, ASMR may refer to a complex emotional interaction or to no emotional

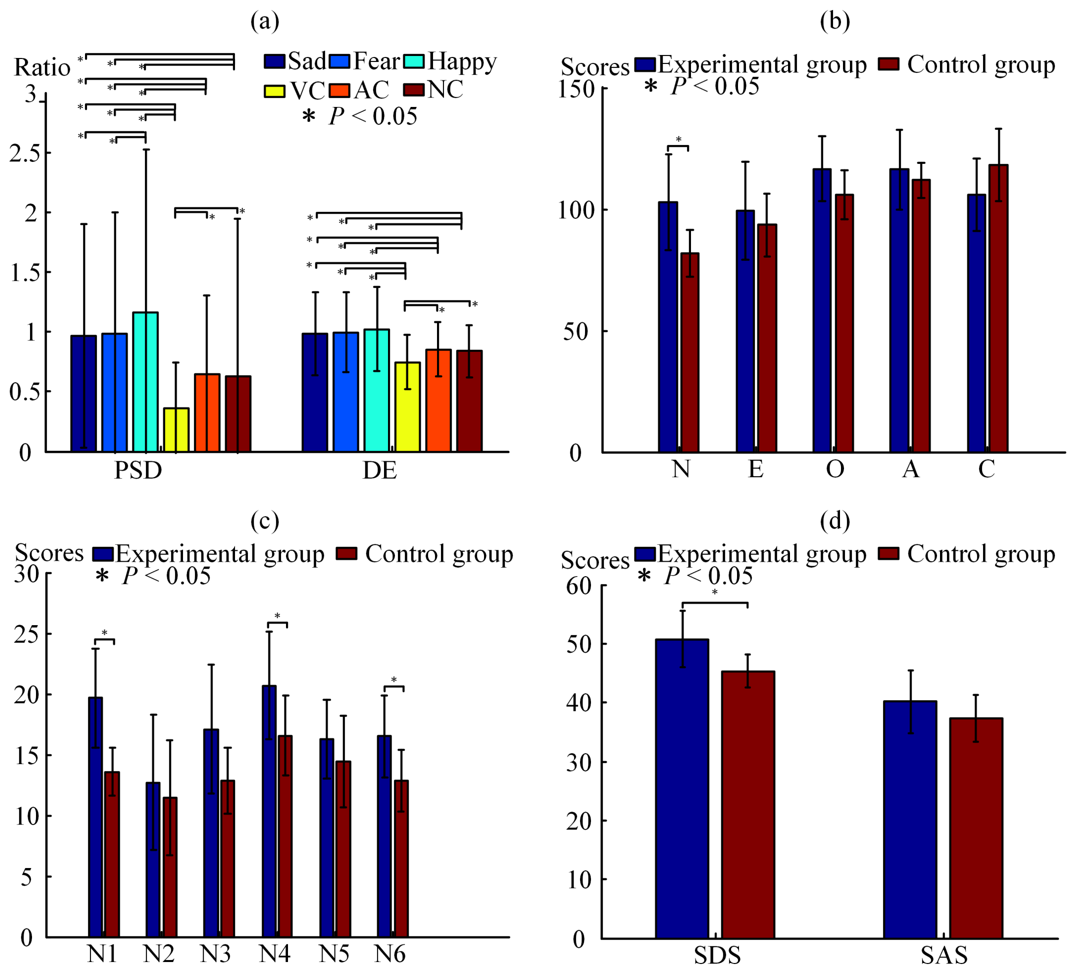

Fig. 6. The statistical results between the experimental and control groups. (a) The post-hoc results by Dunn-Bonferroni test between VC, AC or NC and three emotions; (b) The statistical results on NEO-PI-R' five dimensions by ANOVA; (c) The statistical results on neuroticism's sub-dimensions by ANOVA; (d) The statistical results on SDS and SAS scores by ANOVA.

TABLE VI
THE PEARSON CORRELATION COEFFICIENT BETWEEN SUB-DIMENSIONS OF NEUROTICISM AND SDS OR SAS SCORES

Sub-dimension	SDS's score	SAS's score
Anxiety	0.339	0.377
Self-consciousness	0.204	0.119
Vulnerability	0.150	-0.174

interaction. In this study, VC owned significantly lower PSD and DE on θ, α, β, high γ frequencies than AC. Therefore, VC exhibits better ASMR performance than AC by presenting lower DE and PSD values of EEG.

There was only difference on the visual stimulus between VC and AC. Thus, visual stimulus of VC can further reduce the values of PSD and DE, and involve more emotion processing processes. Moreover, it should be noted that there were not significant differences of DE and PSD on γ frequencies between AC and VC. This may indicate that γ waves are not affected by the visual stimulus. This study also revealed that to compare with RC, VC can suppress DE in high γ frequency, however, AC did not show that reduction. Thus the visual stimulus may induce more cognitive control processes of emotions.

Fig. 4 and Fig. 5 indicated that the post-hoc results of DE were basically in accordance with the one of PSD, and DE had more significant differences between conditions. Thus, DE may be more sensitive than PSD to quantitatively analyze ASMR. To compare with RC, similar reduction of brain actives on θ frequencies in all the brain areas and γ frequencies in frontal, central and parietal areas were revealed under AC, VC and NC. Therefore, audio trigger of ASMR may affect all brain areas on θ frequencies and frontal, central and parietal areas on γ frequencies, and this effects on brain functions may not differ from whitenoise. On α frequencies, VC showed significant differences with AC, NC and RC in all the brain areas. Moreover, to compare with RC, VC can significantly decrease δ waves on left temporal area and central area, and β waves on all the six areas. These suppressions of δ, α and β frequencies above were not be found on AC and NC. These results demonstrate that visual stimulus of VC may involve more cognitive tasks and attention selection than other conditions [33] and affect emotions, such as alertness or anxiety [33], by modulating β frequencies of brain.

ASMR was believed to have a personalized propensity. Previous study reported that ASMR experiencers have significantly greater scores for NEO-PI-R's neuroticism than non-ASMR experiencers [40]. Fredborg indicated that ratings of subjective ASMR intensity in response to ASMR stimuli are positively correlated with the openness and neuroticism dimensions [47]. In this study, the neuroticism was demonstrated to have relationship with ASMR. Moreover, anxiety, self-consciousness and vulnerability were proved to be the main personality characteristics that result in ASMR response. Although, the association between depressive disorder or anxiety disorder and neuroticism was not found, ASMR's experiencers had significantly higher scores in SDS than non-ASMR experiencers. Therefore, ASMR's experiencers may have the tendencies of neuroticism and depressive disorder.

V. Conclusion

This work devotes to explore the ASMR's EEG features and its emotion and personalized propensity. Four conditions, video trigger, audio trigger, whitenoise and rest were analyzed. This study finds that the modulation of ASMR on brain activities is broadband. VC has a remarkably better ASMR performance than AC. Moreover, this study suggests that ASMR may not a kind of a single emotion response to triggers. ASMR has a close relationship with neuroticism and depressive disorder, but without anxiety disorder. The relationship between ASMR and some complex emotion information will be analyzed in the future. Besides, the suppressions of brain activities on NC may have relationship with the effects from VC or AC. More verification experiments will be executed in the future.

VI. Conflicts of Interest

All coauthors have seen and approved manuscript submission. The authors certify that this manuscript is truthful original work without fabrication, fraud, or plagiarism. Lili Li would like to declare on behalf of my coauthors that this manuscript, or any part of it, has not been published previously and will not be submitted elsewhere for publication. Also, Lili Li state that there are no financial or other relations that could lead to a conflict of interest and Lili Li sign for and accept responsibility for releasing this material on behalf of any and all coauthors.

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