

# Androgyny eliminates sex differences in emotional reactivity: ERP and network coupling evidences

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## ABSTRACT

The role of gender role in interpreting sex differences in emotion is unknown. The present study examined how gender role moderates sex differences in emotional reactivity. Event-related potentials (ERP) were recorded in sixty-eight subjects with typical or androgynous gender roles when they passively observed neutral and negative pictures. Behaviorally, typical females (feminine females) reported higher emotional rating than typical males (masculine males), while androgynous males and androgynous females reported no significant differences. Electrophysiologically, we found higher late positive potential (LPP) amplitude in typical females compared to typical males, while this pattern of sex difference was absent in androgynous subjects. The network analysis of EEG data indicates that typical males showed enhanced network coupling strengths between frontal/prefrontal and parietal areas than typical females, which was again absent in androgynous subjects. These findings suggest that gender role is an important determinant in the interpretation of sex differences in emotional reactivity.

## 1. Introduction

The notion that women are more emotional than men has been deeply rooted in the mind of people [1]. However, empirical findings about sex differences in emotion are unclear and inconsistent. Using self-reports of emotional experiences, some studies indicate that women are indeed more emotionally responsive than men [2–4]. Studies using physiological responses to negative stimuli have drawn inconsistent conclusions. Many studies support the notion that women are more reactive to negative stimuli than men [3–8], while others do not find any sex differences in physiological responding [9]. In addition, neuroimaging studies have also come to inconsistent conclusions, several studies show greater amygdala activity in men than in women in the face of negative stimuli [10], which were contrary to the finding [7] that female showed enhanced amygdala activity to negative stimuli. In addition, some studies have found no sex differences in emotional reactivity in the amygdala [1]. Overall, there are obvious inconsistencies in the findings on sex differences in emotional reactivity.

Several studies have stressed the importance of sociocultural factors and gender role characteristics in interpreting the sex differences in

emotions [4,8,11,12]. Sex is innate, which is determined by the sex chromosomes in the human body. However, gender role is a series of behavior norms corresponding to one's sex, which gains from social learning in the process of socialization [13,14]. The traditional view holds that there is only one dimension of gender role, and that masculinity and femininity are two levels of this dimension. Later, Rossi put forward the conception of androgyny, which possesses masculine and feminine characteristics at the same time [15]. Considering that most studies on sex differences in emotional reactivity do not take the gender role into account, it is possible that gender role can be used to explain the inconsistency of previous studies. Specifically, Male and female population, in most cases, are characterized by their predominant masculine and feminine traits, respectively [13]. It is likely that typical samples would show a classic pattern of sex differences with emotional reactivity more pronounced in typical (feminine) females than in typical (masculine) males. More importantly, we are interested in clarifying how the emotion-related sex difference phenomenon should be explained by focusing on the androgynous sample. In more detail, if the sex difference finding is accounted for by sex, we would continue to observe the classic sex difference in emotion in the androgynous

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sample. Alternatively, the sex difference would be compromised or eliminated in the androgynous sample, whose masculinity and femininity are balanced, if socially determined gender roles contribute primarily to the sex difference phenomenon.

Late positive potential (LPP), a positive slow wave that reaches its largest amplitudes in the central parietal zone, is widely used in the study of emotional reactivity (arousal) [16]. A large number of studies have found that negative stimuli can steadily and consistently increase LPP amplitude compared with neutral stimuli [17,18]. Furthermore, EEG analysis using algorithms derived from graph theory has become an increasingly important part of the study of brain networks [19]. Among those, studies have shown that phase locking value (PLV) is successful in inferring the functional connectivity between brain regions using EEG signals [20,21]. Gonuguntal et al. [22] has presented PLV connectivity analysis which is used to identify emotion related functional connectivity pattern and their distinctive associated regions. Thus, EEG-based brain function network analysis was performed to further explore the neural mechanism of sex differences in emotional reactivity. In a summary, the current study aims to investigate the influence of gender role on sex differences in emotional reactivity using EEG techniques. To do this, we had a mixed design with sex (male, female)  $\times$  gender role (typical, androgynous) and condition (neutral, negative) as factors.

## 2. Method

### 2.1. Subjects

To calculate the sample size required in the study, we conducted prior power analyses using G-Power with effect size  $f$  set at 0.25 (middle level), power  $(1 - \beta)$  set at 0.90, number of groups set at 4, number of measurements set at 2 and  $\alpha = .05$ . This showed us that total sample sizes would have to increase up to  $N = 64$ . Based on this, as paid volunteers, 68 right-handed undergraduate or graduate students (18–29 years; mean age = 21.47), who were selected from a large pool of 300 college students that completed the Sex Role Inventory for College Student (CSRI) [14], participated in the experiment. Based on the scores of the subjects on the male-valued scale (M) and female-valued scale (F), each subject was divided into different gender role types by Spence median classification. That is, to calculate the median score of M and F, and then divide the subjects into four types according to the median score (Those with high M and low F were regarded as masculine, with low M and high F were regarded as feminine, while those with high M and high F were regarded as androgynous) [14]. On that basis, these volunteers were divided into 4 groups (see Table 1).

The study was approved by the local Review Board for Human Participant Research, and each participant signed an informed consent form before the experiment. The study was conducted following the ethical principles of the Helsinki Declaration regarding human experimentation [23].

**Table 1**

The information on four groups' volunteers.

	typical		F value	androgynous		F value
	male	female		male	female	
number	17	17		17	17	
mean age	21.24	19.88		23	21.76	
masculine score	75.59 $\pm$ 4.94	56.29 $\pm$ 5.10	125.682***	79.00 $\pm$ 6.36	76.27 $\pm$ 4.62	2.686
feminine score	60.12 $\pm$ 6.07	80.00 $\pm$ 6.15	89.921***	76.47 $\pm$ 4.19	77.00 $\pm$ 4.30	0.132
state anxiety	38.28 $\pm$ 8.14	42.65 $\pm$ 9.99	1.948	38.00 $\pm$ 10.52	39.53 $\pm$ 6.37	0.263
trait anxiety	41.82 $\pm$ 6.33	43.53 $\pm$ 7.58	0.508	40.35 $\pm$ 8.99	39.76 $\pm$ 4.47	0.058
depression	14.12 $\pm$ 7.65	19.77 $\pm$ 5.47	6.131*	16.82 $\pm$ 8.68	16.29 $\pm$ 7.33	0.037

\* $p < .05$ , \*\*\* $p < .001$ .

### 2.2. Materials

The present study used a block-design picture viewing task. The task consisted of two blocks, and each block included 40 picture stimuli that were taken from the International Affective Picture System (IAPS) and its Chinese adapted Version (Chinese Affective Picture System, CAPS). Neutral pictures depicted the scenes of neutral animals and human activities, while unpleasant pictures were composed of scenes of frightening animals, human attack, and body mutilations. The picture stimuli were neutral in block 1, as a non-emotional baseline for computing emotion effect in later condition. Block 2 required subjects to view 40 unpleasant pictures. The order of blocks in the experiment was fixed by starting with block 1 followed by block 2, to avoid potential emotional contamination on the baseline if negative pictures preceded neutral ones.

### 2.3. Procedure

The lab is a quiet, independent room with a soundproof wall. Before the experiment, the subjects were trained with the instruction to ensure that all subjects had a consistent understanding. Subjects were seated approximately 150 cm from the computer screen with the horizontal and vertical visual angles below 6°. The experiment consisted of two blocks. Each trial was initiated by a small black fixation cross on the white computer screen for 300 ms. The offset of the cross was followed by a 1000 ms presentation of the word "attention", reminding subjects to pay close attention to the pictures. Then, a 500–1500 ms blank screen was presented, followed by the onset of picture for 4000 ms. Subjects were instructed to pay close attention and react normally to each stimulus, and experience any feelings it elicited naturally, without any attempts to alter the feelings [24]. After the end of each block, 2 min of rest was used for subjects to recover their emotion to the baseline level. Before and after each block, subjects were required to rate their mood state by a self-report 7-point scale (1: neutral, non-emotional to 7: extremely unpleasant). After each block, participants were required to rate the extent of close attention and natural response they directed to the pictures (1: not successful at all; 7: completely successful). At the end of the experiment, subjects rated the arousal and valence of every picture (arousal: 1 = not arousing at all, 9 = extremely arousing; valence: 1 = extremely unpleasant, 9 = extremely pleasant) (see Fig. 1). Prior to each block, subjects were presented with eight trials for practice, where the pictures were emotionally similar to those used in the formal experiment of that block.

### 2.4. ERP recording and analysis

EEG was recorded at 500 Hz using an elastic cap (Brain Products) with 64 scalp sites according to the extended 10–20 system [25].

Based on a large number of previous studies, LPP was most pronounced in the central parietal area [17,18]. According to this, we chose the average amplitude of the three channels (CP1, CPz, CP2) to

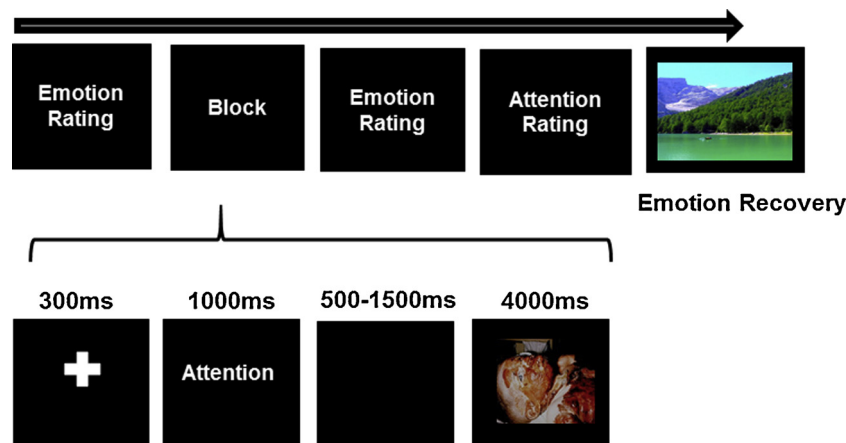


Fig. 1. Schematic illustration of the experimental procedure.

calculate the LPP.

To construct network, 25 electrodes (i.e., AF3, Fz, F1, F3, FCz, Cz, C1, C3, CP1, CP3, Pz, P3, Oz, O1, AF4, F2, F4, C2, C4, CPz, CP2, CP4, P4, POz, O2) were selected, which covers representative sites of frontal, parietal, temporal and occipital scalp regions. Phase locking value (PLV) was used to measure the functional network in the current study, which is defined as:

$$PLV = \left| \frac{1}{N} \sum_{j=0}^{N-1} e^{i(\varphi_x(jt) - \varphi_y(jt))} \right| \quad (1)$$

Where  $t$  is the cycle,  $n$  is the sample size,  $\varphi_x(t)$  and  $\varphi_y(t)$  are the instantaneous phases of the two signals. We used four typical indicators to describe the efficiency of brain network connectivity. Clustering coefficient (C) is defined as the degree of clustering of nodes in a network [26], and local efficiency (Le) is defined as the ability of information contained in nodes to be transmitted locally in the network [27]. In addition, global efficiency (Ge) is defined as the average of relevant brain networks [28] and the characteristic path length (L) is defined as the degree of connectivity in the network [29].

All statistical analysis was implemented in SPSS. The degrees of freedom of the F-ratio was corrected according to the Greenhouse–Geisser method for any violations of sphericity and Bonferroni correction was used for post hoc pairwise comparisons. We also computed Bayes factors ( $BF_{10}$ ) using JASP with default prior width [30].

### 3. Result

#### 3.1. Manipulation check

To test the extent to which participants naturally attended to the pictures, we examined their reported attention rating. The scores for each condition were significantly higher than the midpoint of the rating scale (i.e., 4) [neutral:  $t(67) = 7.864$ ; negative:  $t(67) = 17.240$ ,  $ps < .001$ ; both  $BF_{10} > 100$ ] (see Fig. 2A). To examine whether attention involvement is different across conditions and different groups, we submitted the attention rating to a 2 (negative, neutral) \* 2 (sex: man, woman) and 2 (gender role: masculine, feminine) mixed-design ANOVA. The results showed higher attention rating in negative ( $M = 5.91 \pm 0.12$ ) than in neutral ( $M = 5.35 \pm 0.18$ ) block ( $F(1,64) = 11.33$ ,  $p < .001$ ; partial  $\eta^2 = 0.150$ ;  $BF_{10} > 100$ ), most likely due to negative attention bias. There were no other significant main or interaction effects (all  $ps > .294$ ), suggesting that different samples attended to the pictures similarly.

To test valence and arousal, we analyzed emotional valence and arousal rating by a repeated-measures ANOVA, with condition (neutral and negative) as a within-subjects factor, and sex (male and female),

gender role (typical and androgynous) as between-subjects factors. Valence ratings were significantly different among conditions,  $F(1, 64) = 207.303$ ,  $p < .001$ ; partial  $\eta^2 = .764$ ;  $BF_{10} > 100$ . The valence scores were significantly higher in neutral ( $M = 6.349 \pm 0.145$ ) compared to negative ( $M = 3.493 \pm 0.127$ ),  $t(67) = 16.006$ ,  $p < .001$ ;  $BF_{10} > 100$  (see Fig. 2B). Arousal ratings were also significantly different among conditions,  $F(1,64) = 198.157$ ,  $p < .001$ ; partial  $\eta^2 = .762$ ;  $BF_{10} > 100$ . Participants reported higher emotional arousal in negative ( $M = 4.929 \pm 0.182$ ) than in neutral block ( $M = 2.341 \pm 0.149$ ),  $t(67) = 13.320$ ,  $p < .001$ ;  $BF_{10} > 100$ . There were no other significant main or interaction effects (all  $ps > .25$ ) (see Fig. 2C).

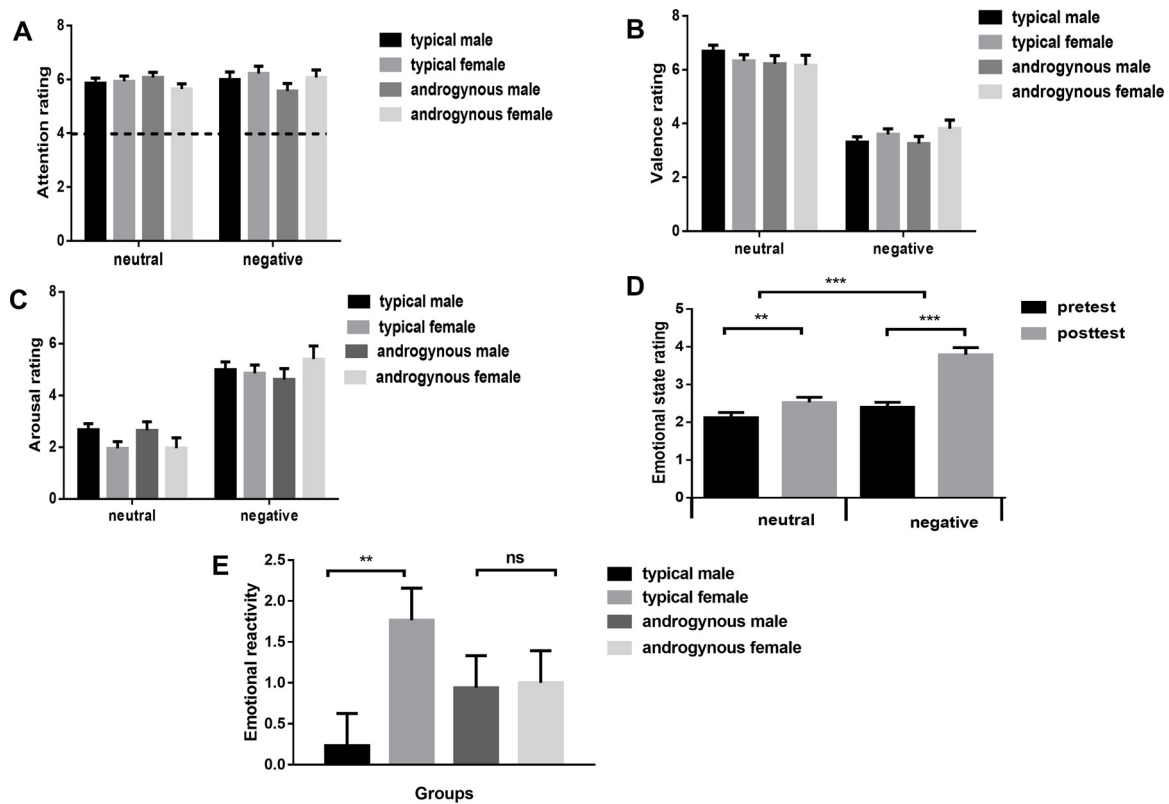
#### 3.2. Behavioral performance

Participants' emotional state was analyzed by a repeated-measures ANOVA with time (pre and post), condition (neutral and negative) as within factors and sex (male and female), gender role (typical and androgynous) as between factors. Considering that typical men and women differ in self-reported depression, depression rating was taken as a covariate here and in following EEG analyses. We found a significant main effect of time [ $F(1,63) = 5.049$ ,  $p = .028$ ; partial  $\eta^2 = .074$ ;  $BF_{10} > 100$ ], a significant main effect of condition [ $F(1,63) = 4.679$ ,  $p = .034$ ; partial  $\eta^2 = .069$ ;  $BF_{10} > 100$ ], and a significant time  $\times$  condition interaction [ $F(1,63) = 5.896$ ,  $p = .018$ ; partial  $\eta^2 = .086$ ;  $BF_{10} > 100$ ]. As shown in Fig. 2D, simple effect analysis showed higher emotion intensity after than before watching pictures in both conditions; while this increase was more pronounced in negative than in neutral condition [ $t(67) = 4.864$ ,  $p < .001$ ;  $BF_{10} > 100$ ].

Furthermore, we computed an index of emotional reactivity and then performed group comparisons. The emotional reactivity is defined as the after-before change of emotional state rating in the negative condition minus that in the neutral condition. We found a significant sex \* gender role interaction [ $F(1,63) = 5.802$ ,  $p = .019$ ; partial  $\eta^2 = .084$ ;  $BF_{10} = 0.160$ ]. As shown in Fig. 2E and confirmed in follow-up tests of simple effects, typical females experienced larger emotional reactivity than typical males [ $F(1,63) = 7.987$ ,  $p = .006$ ; partial  $\eta^2 = .113$ ;  $BF_{10} = 1.688$ ], while there were no significant differences between androgynous males and androgynous females [ $F(1,63) = .310$ ,  $p = .579$ ; partial  $\eta^2 = .005$ ;  $BF_{10} = 0.130$ ].

#### 3.3. ERP result

To test the characteristics of emotional arousal over time, we divided the early LPP (300–1900 ms) into 4 equal 400 ms time segments (300–700, 700–1100, 1100–1500, and 1500–1900 ms, see Fig. 3). We ran a repeated-measures ANOVA with condition (neutral and negative), time segments as within factors and sex (male and female), gender role



**Fig. 2.** (A) The extent to which participants naturally attended to the pictures and the result of emotional valence (B) and arousal (C) rating. The results of emotional state rating during each condition (D) and emotional reactivity (Emotional reactivity is defined as the after-before change of emotional state rating in the negative condition minus that in the neutral condition) between groups (E). Error bars indicate standard error of the mean. \*\* $p < .01$ , \*\*\* $p < .001$ .

(typical and androgynous) as between factors, with depression score as a covariate. We found a significant interaction involving condition \* time segment \* sex \* gender role [ $F(3,189) = 5.008, p = .002$ ; partial  $\eta^2 = .074$ ;  $BF_{10} > 100$ ]. We then performed simple effect analysis by splitting the time segment, with the results as follows.

During 300–700 ms, we found a significant main effect of condition [ $F(1,63) = 7.087, p = .010$ ; partial  $\eta^2 = .101$ ;  $BF_{10} > 100$ ], with the amplitudes evoked by negative pictures ( $3.663 \pm 0.376$ ) significantly larger than those evoked by neutral pictures ( $2.125 \pm 0.335$ ). More importantly, we found a significant condition \* sex \* gender role [ $F(1,63) = 5.877, p = .018$ ; partial  $\eta^2 = .09$ ;  $BF_{10} > 100$ ] interaction. We then calculated the index of emotional reactivity by subtracting LPP amplitudes in the neutral condition from those in the negative condition. Follow-up tests of simple effects showed that typical females had larger size of emotional reactivity, indexed by negative-neutral differences in LPPs, than typical males [ $F(1,63) = 9.015, p = .004$ ; partial  $\eta^2 = .125$ ;  $BF_{10} = 10.893$ ], while there was no difference between androgynous males and androgynous females [ $F(1,63) = 0.228, p = .634$ ; partial  $\eta^2 = .004$ ;  $BF_{10} = 0.381$ ].

We did not find any inter-group differences during other time segments (see Fig. 4).

### 3.4. Network analysis

As shown in Fig. 5A, compared with neutral images, negative images induced increased network coupling strengths in all groups. And in the corresponding network properties, we found that, compared with neutral images, negative images had higher clustering coefficient [ $t(67) = 6.765, p < .001$ ;  $BF_{10} > 100$ ], global efficiency [ $t(67) = 6.704, p < .001$ ;  $BF_{10} > 100$ ] and local efficiency [ $t(67) = 6.762, p < .001$ ;  $BF_{10} > 100$ ], and lower characteristic path length [ $t(67) = 6.716, p < .001$ ;  $BF_{10} > 100$ ]. Furthermore, we performed group

comparisons concerning the brain network topologies for the negative condition, which is vital for emotion induction (see Fig. 5B). We observed that typical males showed enhanced network coupling strengths between brain areas including frontal/prefrontal, parietal and occipital lobe compared with typical females. And in corresponding network properties, we found a significant sex \* gender role interaction [ $F_s(1,64) > 5.302, p_s < .025$ ;  $BF_{10} > 100$ ]. As shown in Fig. 5B and confirmed in follow-up tests of simple effects, compared with typical females, typical males had higher clustering coefficient [ $F(1,64) = 22.951, p < .001$ ;  $BF_{10} > 100$ ], global efficiency [ $F(1,64) = 23.977, p < .001$ ;  $BF_{10} > 100$ ] and local efficiency [ $F(1,64) = 23.906, p < .001$ ;  $BF_{10} > 100$ ], and lower characteristic path length [ $F(1,64) = 33.674, p < .001$ ;  $BF_{10} > 100$ ]. However, there was no significant difference between androgynous males and androgynous females [ $F_s < 2.736, p > 0.103$ ;  $.87 < BF_{10} < .90$ ].

$p < .001$ ); (B) (left and right) Brain network topology of the significant difference between males and females in the negative condition (the red and blue indicate the increased and decreased network coupling strengths from males to females, respectively,  $p < .001$ ) and (middle) the corresponding network properties. \* $p < .05$ , \*\*\* $p < .001$

## 4. Discussion

Our manipulation check showed that participants, irrespective of sex and gender role typicality, paid similar close attention to the pictures. In addition, valence and arousal rating showed that negative images were valid in inducing negative emotional experiences in the subjects. As predicted, we found significant differences in emotional reactivity between typical males and typical females. And typical females showed larger emotional reactivity than typical males both in behavioral and LPP amplitudes. This conclusion was consistent with previous studies that females were emotionally more reactive than

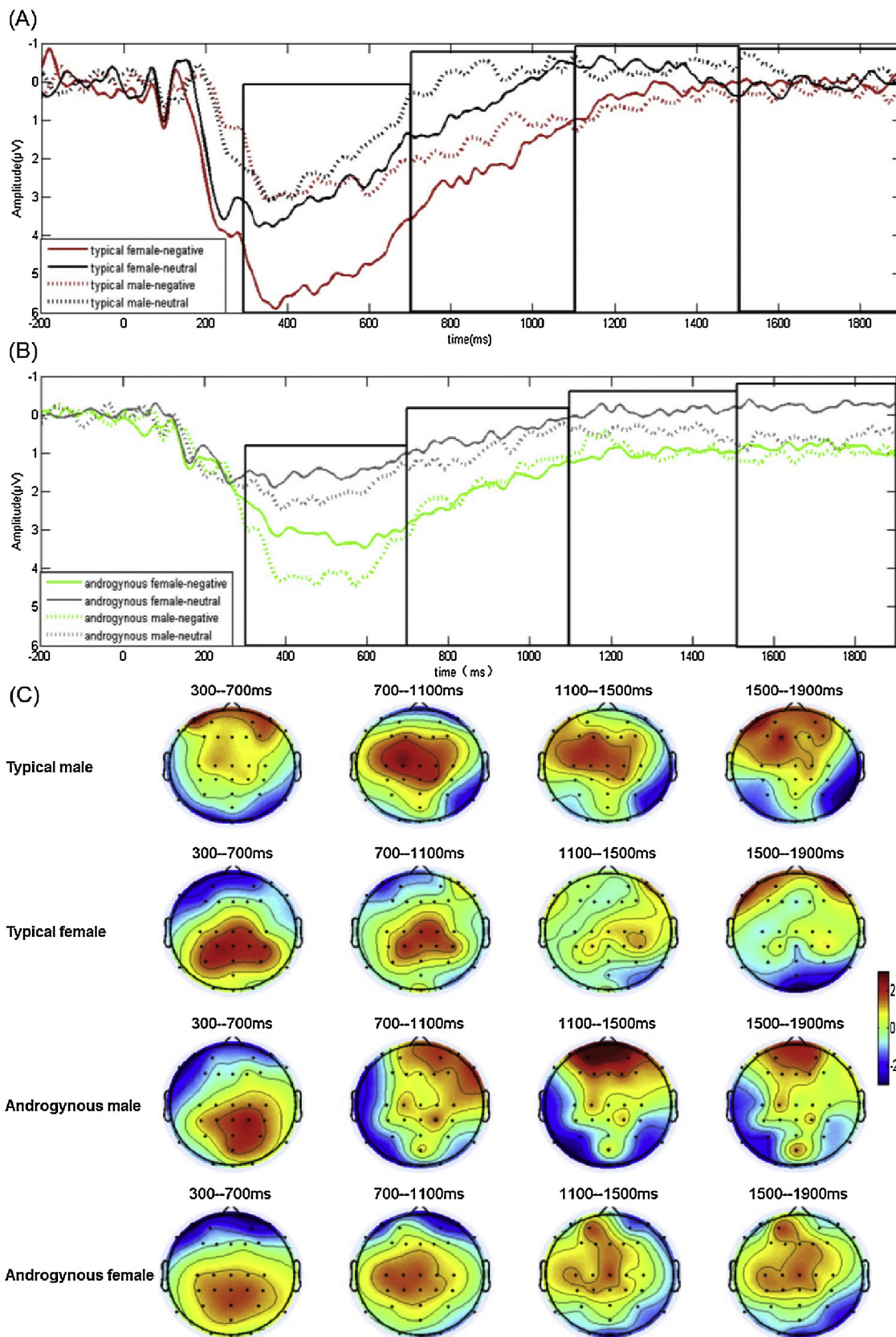


Fig. 3. Averaged ERPs elicited by negative and neutral pictures and topographic maps in each group. (A) The LPPs in typical groups and (B) in androgynous groups from 300–1900 ms time window. (C) the topographic maps corresponding to the emotional reactivity (negative-neutral difference ERPs).

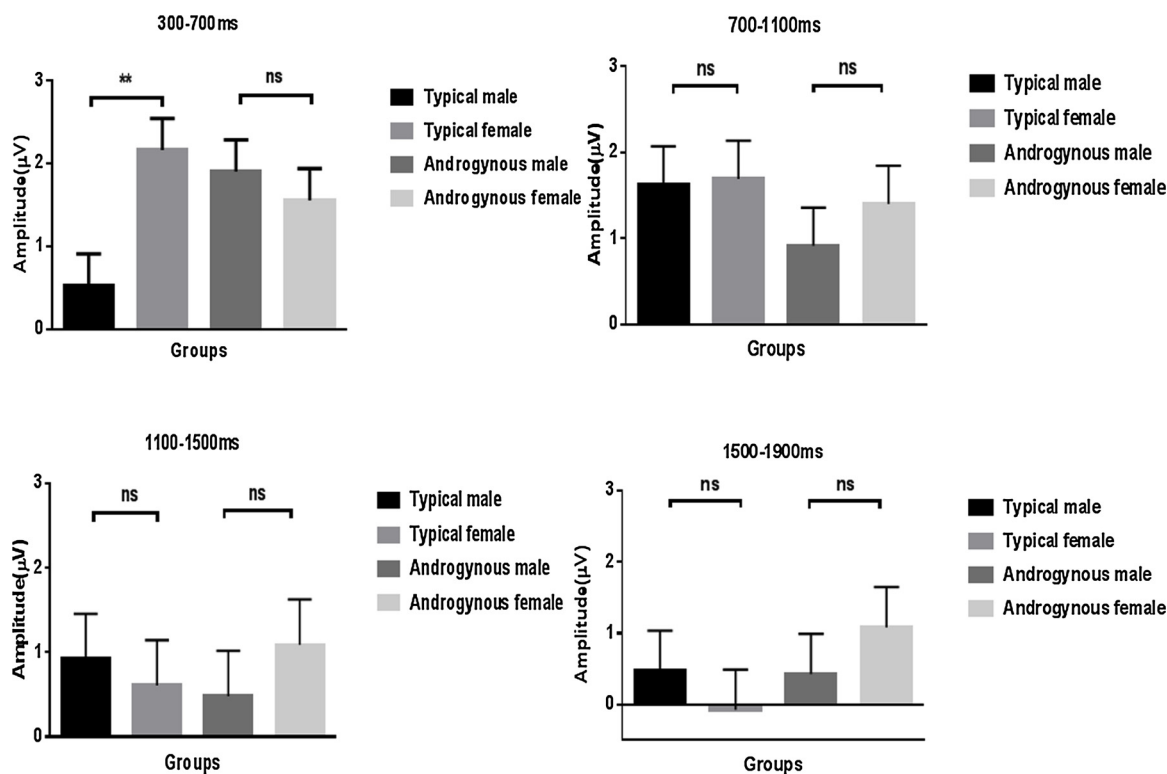


Fig. 4. The result of LPP amplitude induced by the neutral and negative picture in different groups. Error bars indicate standard error of the mean.  $**p < .01$ .

males [4,7,8]. Furthermore, the typical males showed enhanced network coupling strengths between brain areas including frontal/pre-frontal, parietal and occipital scalp regions compared with the typical females when viewing negative images. Previous studies have shown

that the use of spontaneous (automatic) reappraisal was associated with decreased activation in emotion generative regions and increased pre-frontal and parietal activity in response to negative stimuli [31]. Consistent with this study, our finding of enhanced network coupling

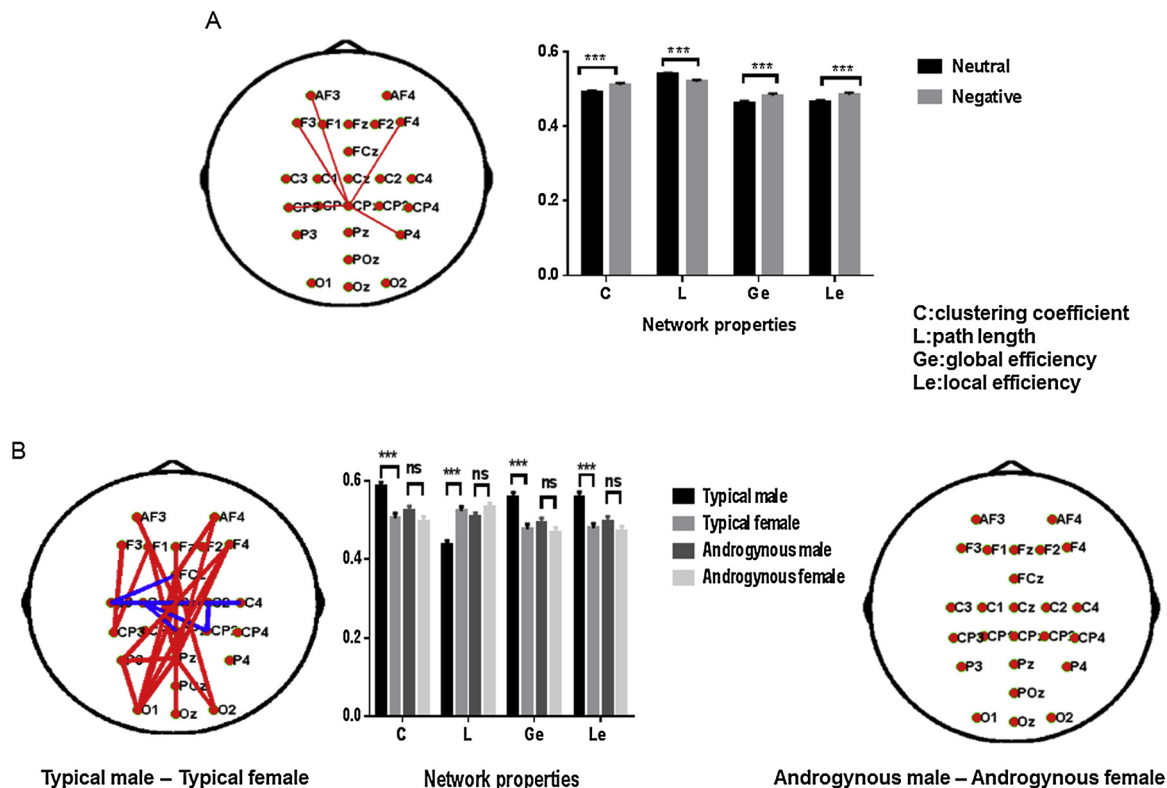


Fig. 5. (A) Brain network topology and property differences between neutral and negative conditions (the red line denotes increased network coupling strengths in negative relative to neutral condition).

between frontal and parietal/occipital regions, suggests that males may have down-regulated negative emotions spontaneously during the presentation of negative images. This explanation was also supported by the studies of sex difference in emotion regulation, which observed more efficient frontal regulation of negative emotional reactivity in amygdala [1]. In brief, these pieces of evidence suggest that gender-consistent males may be better at automatic emotion regulation compared to those females.

More importantly, we found that there was no significant difference in emotional reactivity between androgynous males and androgynous females, irrespective of whether emotional state rating, LPP amplitudes or network properties were concerned. Androgyny, which possesses masculine and feminine characteristics at the same time [15], has been reported to enjoy a higher level of mental and social adjustment compared to other gender roles, including higher self-esteem, less internalizing problems and increased adaptive flexibility [32,33]. Based on these pieces of evidence, we infer that androgynous subjects, irrespective of sex, may be less susceptible to the impact of negative stimuli compared with other gender roles (i.e. masculinity and femininity). It needs to be noted that androgynous males and females were equated in both masculine and feminine gender roles, and the two samples differ only in biological sex. After controlling the influences of gender roles, we observed no significant sex differences in emotional reactivity. This suggests that biological sex alone does not moderate human's emotional reactivity, contrary to prior studies of sex differences which observed enhanced emotional reactivity in females than in males when gender roles were not considered [1,7]. That is, the current study extends existing knowledge by suggesting that the phenomenon of sex differences in emotional reactivity to negative stimuli should be primarily accounted for by socially shaped gender roles. Gender roles should not be omitted in future study of sex differences in emotional reactivity.

Several limitations should be noted. Firstly, the current study did not assess individual differences in spontaneous emotion regulation. Though our data of manipulation check showed that subjects effectively attended and responded naturally to the pictures, we cannot rule out the possibility that emotion regulation strategies were spontaneously initiated when negative images were presented. Future studies should collect the data of spontaneous emotion regulation in order to control interindividual differences in trait emotion regulation. In addition, the present study did not directly compare the differences in emotional reactivity between androgyny and other gender roles (i.e. masculinity and femininity). Though our findings suggest that gender roles may play a primary role in the interpretation of sex differences in emotional reactivity, how feminine and masculine gender roles moderate sex differences in emotion needs to be explored in future studies.

#### Credit author statement

JiaJin Yuan conceived the study; Kang Yu, YuanYuan Liao, DaoLing Fu, ShengDong Cheng And QuanShan Long carried out experiments; Kang Yu, YuanYuan Liao and Peng Xu analyzed experimental results; Kang Yu, YuanYuan Liao, DaoLing Fu and JiaJin Yuan wrote the manuscript.

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#### References

- [1] K. McRae, K.N. Ochsner, I.B. Mauss, J.J.D. Gabrieli, J.J. Gross, Gender differences in emotion regulation: an fMRI study of cognitive reappraisal, *Group Process.*

- Intergroup Relat. 11 (2) (2008) 143–162.
- [2] J.J. Yuan, Y.J. Luo, J.H. Yan, X.X. Meng, F.Q. Yu, H. Li, Neural correlates of the females' susceptibility to negative emotions: an insight into gender-related prevalence of affective disturbances, *Hum. Brain Mapp.* 30 (11) (2009) 3676–3686.
- [3] J.J. Yuan, J.M. Yang, J. Chen, X.X. Meng, H. Li, Enhanced sensitivity to rare, emotion-irrelevant stimuli in females: neural correlates, *Neuroscience* 169 (2010) 1758–1767.
- [4] M.M. Bradley, M. Codispoti, D. Sabatinelli, P.J. Lang, Emotion and motivation. II: sex differences in picture processing, *Emotion* 1 (2001) 300–319.
- [5] E.K.T. Gardener, A.R. Carr, A. MacGregor, K.L. Felmingham, Sex differences and emotion regulation: an event-related potential study, *PLoS One* 8 (10) (2013) e73475, <https://doi.org/10.1371/journal.pone.0073475>.
- [6] J.S. Stevens, S. Hamann, Sex differences in brain activation to emotional stimuli: a meta-analysis of neuroimaging studies, *Neuropsychologia* 50 (2012) 1578–1593.
- [7] G. Domes, L. Schulze, M. Böttger, A. Grossmann, K. Hauenstein, P.H. Wirtz, M. Heinrichs, S.C. Herpertz, The neural correlates of sex differences in emotional reactivity and emotion regulation, *Hum. Brain Mapp.* 31 (2010) 758–769.
- [8] A.M. Kring, A.H. Gordon, Sex differences in emotion: expression, experience, and physiology, *J. Soc. Personality Psychol.* 74 (1998) 686–703.
- [9] M.M. Kelly, A.R. Tyrka, G.M. Anderson, L.H. Price, L.L. Carpenter, Sex differences in emotional and physiological responses to the Trier social stress test, *J. Behav. Ther. Exp. Psychiatry* 39 (2008) 87–98.
- [10] A. Schienle, A. Schafer, R. Stark, B. Walter, D. Vaitl, Gender differences in the processing of disgust- and fear-inducing pictures: an fMRI study, *NeuroReport* 16 (2005) 277–280.
- [11] O. Lungu, S. Potvin, A. Tikász, A. Mendrek, Sex differences in effective fronto-limbic connectivity during negative emotion processing, *Psychoneuroendocrinology* 62 (2015) 180–188, <https://doi.org/10.1016/j.psypneuen.2015.08.012>.
- [12] M. Grossman, W. Wood, Sex differences in intensity of emotional experience: a social role interpretation, *J. Pers. Soc. Psychol.* 65 (1993) 1010–1022.
- [13] D.Z. Liu, H.X. Huang, F.Q. Jia, Q. Gong, Q. Huang, X. Li, A new sex-role inventory (CSRI-50) indicates changes of sex role among Chinese college students, *Acta Psychol. Sin.* 43 (6) (2011) 639–649.
- [14] M. Qian, G. Zhang, S. Luo, S. Zhang, Sex role inventory for college students (CSRI), *Chin. J. Psychol.* 32 (1) (2000) 99–104.
- [15] R.D. Ashmore, Sex, gender, and individual, in: L.A. Pervin (Ed.), *Handbook of Personality: Theory and Research*, The Guilford Press, New York/ London, 1990, pp. 487–521.
- [16] G.H. Proudfit, J.P. Dunning, D. Foti, A. Weinberg, Temporal dynamics of emotion regulation, *Handbook of Emotion Regulation*, Guilford Publications, 2013, pp. 43–57.
- [17] B.N. Cuthbert, H.T. Schupp, M.M. Bradley, N. Birbaumer, P.J. Lang, Brain potentials in affective picture processing: covariation with autonomic arousal and affective report, *Biol. Psychol.* 52 (2) (2000) 95–111.
- [18] H.T. Schupp, J. Markus, A.I. Weike, A.O. Hamm, Emotional facilitation of sensory processing in the visual cortex, *Psychol. Sci.* 14 (1) (2003) 7–13.
- [19] M. Vourkas, E. Karakonstantaki, P.G. Simos, V. Tsirka, M. Antonakakis, M. Vamvoukas, C. Stam, S. Dimitriadis, S. Micheloyannis, Simple and difficult mathematics in children: a minimum spanning tree EEG network analysis, *Neurosci. Lett.* 576 (2014) 28–33.
- [20] M. Hassan, P. Benquet, A. Biraben, C. Berrou, O. Dufour, F. Wendling, Dynamic reorganization of functional brain networks during picture naming, *Cortex* 73 (2015) 276–288.
- [21] J.-S. Kang, U. Park, V. Gonuguntla, K.C. Veluvolu, M. Lee, Human implicit intent recognition based on the phase synchrony of EEG signals, *Pattern Recognit. Lett.* 66 (2015) 144–152.
- [22] V. Gonuguntla, R. Mallipeddi, K.C. Veluvolu, Identification of emotion associated brain functional network with phase locking value, August, 2016 38<sup>th</sup> Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), IEEE, 2016, pp. 4515–4518.
- [23] World Medical Organization, Declaration of Helsinki (1964), *Br. Med. J.* 313 (1996) 1448–1449.
- [24] H. Ohira, M. Nomura, N. Ichikawa, T. Isowa, T. Iidaka, A. Sato, et al., Association of neural and physiological responses during voluntary emotion suppression, *Neuroimage* 29 (3) (2006) 721–733.
- [25] X. Li, X.X. Meng, H. Li, J.M. Yang, J.J. Yuan, The impact of mood on empathy for pain: evidence from an EEG study, *Psychophysiology* 2017 (2017) 1–12, <https://doi.org/10.1111/psyp.12882>.
- [26] E. Cozzo, M. Kivelä, M.D. Domenico, A. Solé, A. Arenas, S. Gómez, M.A. Porter, Y. Moreno, Clustering coefficients in multiplex networks, *New J. Phys.* 17 (2013) 1–19, <https://doi.org/10.1088/1367-2630/17/7/073029>.
- [27] D. Otten, Fraud Detection in a Cellular Communications System, WO Application. doi: WO1995034177A9 (1995).
- [28] B. Paprocki, J. Szczepanski, Transmission efficiency in ring, brain-inspired neuronal networks. Information and energetic aspects, *Brain Res.* 1536 (2013) 135–143, <https://doi.org/10.1016/j.brainres.2013.07.024>.
- [29] A.I. Reppas, K. Spiliotis, C.I. Siettos, Turning the average path length of complex networks and its influence to the emergent dynamics of the majority-rule model, *Math. Comput. Simul.* 109 (2014) 186–196.
- [30] H. Jeffreys, *The Theory of Probability*, OUP Oxford, 1998.
- [31] E.M. Drabant, K. McRae, S.B. Manuck, A.R. Hariri, J.J. Gross, Individual differences in typical reappraisal use predict amygdala and prefrontal responses, *Biol. Psychiatry* 65 (2009) 367–373, <https://doi.org/10.1016/j.biopsych.2008.09.007>.
- [32] C.L. Martin, R.E. Cook, N.C.Z. Andrews, Reviving androgyny: a modern day perspective on flexibility of gender identity and behavior, *Sex Roles* (2016) 1–12, <https://doi.org/10.1007/s11199-016-0602-5>.
- [33] R.E. Pauletti, M. Menon, P.J. Cooper, C.D. Aults, D.G. Perry, Psychological androgyny and children's mental health: a new look with new measures, *Sex Roles* (2016) 1–14, <https://doi.org/10.1007/s11199-016-0627-9>.