

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23

Culture and Gender Modulate dlPFC Integration in the Emotional Brain: Evidence from Dynamic Causal
Modeling

Zachary H. Pugh¹, Jiali Huang², Joseph Leshin³, Kristen A. Lindquist³, Chang S. Nam^{✉2}

¹Department of Psychology, North Carolina State University, Raleigh, NC, United States

²Department of Industrial and Systems Engineering, North Carolina State University, Raleigh, NC,
United States

³Department of Psychology and Neuroscience, University of North Carolina at Chapel Hill, Chapel Hill,
NC, United States

Please direct all correspondence to Chang S. Nam at csnam@ncsu.edu

Data availability statement. The data obtained for this manuscript is available upon request to the
corresponding author.

Declarations. This research was partly supported by the National Science Foundation (NSF) under Grant
NSF BCS-1551688. Any opinions, findings, and conclusions or recommendations expressed in this
material are those of the authors and do not necessarily reflect the views of the NSF. The authors declare
that they have no competing interests in the publication of this manuscript.

Abstract

24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50

Past research has recognized culture and gender variation in the experience of emotion, yet this has not been examined on a level of effective connectivity. To determine culture and gender differences in effective connectivity during emotional experiences, we applied dynamic causal modeling (DCM) to electroencephalography (EEG) measures of brain activity obtained from Chinese and American participants while they watched emotion-evoking images. Relative to US participants, Chinese participants favored a model bearing a more integrated dorsolateral prefrontal cortex (dlPFC) during fear v. neutral experiences. Meanwhile, relative to males, females favored a model bearing a less integrated dlPFC during fear v. neutral experiences. A culture-gender interaction for winning models was also observed; only US participants showed an effect of gender, with US females favoring a model bearing a less integrated dlPFC compared to the other groups. These findings suggest that emotion and its neural correlates depend in part on the cultural background and gender of an individual. To our knowledge, this is also the first study to apply both DCM and EEG measures in examining culture-gender interaction and emotion.

Keywords. Emotion, fear, culture, gender

1. Introduction

1.1 Emotion is situated

Emotion categories are not monolithic entities but are highly situated phenomena (Barrett, 2017; Ellsworth, 2013; Mesquita et al., 2016). There is evidence that feelings (Coifman et al., 2016), behaviors (Y.-P. Chang & Algoe, 2020), physiology (Kreibig, 2010; Siegel et al., 2018) and cognitions (Power & Dalgleish, 2015) accompanying emotions can vary substantially across contexts. There is also evidence that emotional brain states vary across stimulus type (Yuan et al., 2019), situation (Wilson-Mendenhall et al., 2011), personality traits (Lim et al., 2012), cultural background (Kwon et al., 2013), and gender (Fischer et al., 2004).

In the present study, we contribute to the extant research on individual differences in emotion by

51 examining how culture, gender, and their interaction alter the effective connectivity in emotional brain
52 states. Culture describes the socioecological context that individuals are exposed to throughout their
53 lifetime, as well as the values, norms, icons, and beliefs to which people adhere (Eagly, 2013; Gelfand et
54 al., 2017; Markus & Kitayama, 1991). Gender refers to the meanings that individuals within a culture
55 ascribe to male and female categories (Wood & Eagly, 2002). There is evidence that emotion emerges
56 from the interaction of broadscale networks spanning prefrontal, paralimbic, limbic, and sensory cortices
57 that support basic processes such as the generation of visceral states, representation of semantic
58 knowledge and cognitive control (Barrett & Satpute, 2013; Cunningham et al., 2013; Lindquist &
59 Barrett, 2012b; Pessoa, 2018; Satpute & Lindquist, 2019). The specific combination of these networks is
60 highly situated and is influenced by factors such as culture and gender (Barrett, 2017; Wilson-
61 Mendenhall et al., 2013). Yet relatively little research has examined how culture, gender, and their
62 interaction influence effective connectivity between brain regions during emotional experience.

63 To this end we apply a dynamic causal modeling (DCM) analysis to electroencephalography
64 (EEG) recordings obtained from participants viewing fear-eliciting and neutral images. In contrast to
65 imaging techniques such as fMRI, EEG offers a unique advantage of high temporal resolution needed to
66 capture the causal dynamics of emotion processing (Gevins, 1997; Nam, 2020). Unlike functional
67 connectivity, which measures correlations of activity among brain regions, DCM is a measure of
68 effective connectivity, allowing us to quantify the directed influences among neuronal populations in a
69 brain network and make inferences of causal influence between those brain regions (Brown & Friston,
70 2012; Friston et al., 2003; Huang & Nam, 2020; Kiebel et al., 2008). The emotion category of fear was
71 chosen as an example of an unpleasant, high arousal emotion; the neural correlates of unpleasant
72 affective experiences (Lindquist et al., 2016) and fearful experiences (Lindquist & Barrett, 2012) have
73 been extensively studied. Because of the strong association between the amygdala (responsible for
74 attending to and resolving uncertainty in the environment, including threats; Adolphs, 2008) and fear
75 experience (itself an instance of threat and uncertainty), the amygdala and its connections provided a
76 straightforward starting point for developing a model space for fear, comprising a set of frontal-limbic
77 regions including the dorsolateral prefrontal cortex (dlPFC), anterior cingulate cortex (ACC),

78 ventromedial prefrontal cortex (vmPFC), and primary visual cortex (V1).

79 By focusing on how remote neuronal dynamics influence or cause each other in different
80 contexts—rather than limiting our interpretations to mean-level regional activity that is more commonly
81 reported in analyses of brain activity (Kim et al., 2017, 2019; Wittenberg et al., 2017)—DCM can extend
82 our understanding of the neural processes (functional integration of the brain) that underlie human
83 emotional experience. We hypothesized that the effective connectivity networks would differ between
84 male and female participants and between US and Chinese participants. To our knowledge, no
85 neuroimaging study has simultaneously examined the roles of both culture and gender with respect to the
86 causal functional architecture of emotional experiences.

87 **1.2 Effects of Culture, Gender, and their Interaction on Emotion**

88 Cultural background has been repeatedly implicated in emotion generation and regulation. For instance,
89 how emotion is externalized and communicated—to include language, facial expression, vocalization,
90 and posture—is known to vary across cultures (Gendron, 2017). Bonassi et al. (2021) found that
91 Japanese participants' categorization of emotion in facial expression varies with the expressor's ethnicity.
92 A language of one culture may encode different meanings for emotion categories in a manner that does
93 not align with other cultures (Jackson et al., 2019). Culture-bound syndromes have been documented,
94 such as *ataque de nervios* (Guarnaccia et al., 1989), *hwabyeong* (Chiao et al., 2013), and *taijin kyofusho*
95 (Kleinknecht et al., 1997; but see also Suzuki et al., 2003). Such emotion words play a role in
96 conceptualization of emotion during the construction of emotional experiences, which then shape
97 emotional processing at the level of neural networks (Brooks et al., 2016).

98 In addition to emotion conceptualization, studies in social psychology and neurophysiology
99 have found that emotion regulation varies with culture, a finding often attributed to the cultural variation
100 along an individualist-collectivist dimension: whereas Eastern cultures prioritize harmony with the
101 group, Western backgrounds value independence and individuality (Butler et al., 2007; de Greck et al.,
102 2012; Han & Ma, 2014; Lindquist & Barrett, 2008; Park & Huang, 2010). In one study involving an
103 emotion suppression task, Asian participants showed significantly lower late positive potential compared
104 to European American participants, corroborating an account of culturally ingrained emotion regulation

105 (Murata et al., 2013). Much of this research has implicated the dorsolateral prefrontal cortex (dlPFC)
106 (Han & Ma, 2014), a region involved in the central executive network and implicated in emotion
107 regulation (MacDonald et al., 2000). Still, to our knowledge the effect of culture on effective
108 connectivity of emotional brain states has yet to be investigated. Given the cultural differences in the
109 recruitment of the dlPFC in emotion regulation and given the cultural differences in the emphasis on
110 emotion regulation, our first hypothesis (H1) is that compared to US participants, Chinese participants
111 will show greater involvement of prefrontal regions during instances of fearful experiences.

112 Gender is another thoroughly studied dimension of individual differences in emotion. A
113 common finding has been that females tend to self-report stronger negative affect than males (Fujita et
114 al., 1991; Knyazev et al., 2010; Ma-Kellams & Wu, 2020; Zhang et al., 2017). Greater self-reported
115 negative affect in women is also associated with more sustained amygdala responses to multiple
116 presentations of negative stimuli (Andreano et al., 2014), and women consistently show greater amygdala
117 activity to negative stimuli than men across the neuroimaging literature (Stevens & Hamann, 2012).
118 These differences may be related to differences in amygdala-prefrontal connectivity: in a task involving
119 negative stimuli, women self-reported more extreme negative affect while men showed higher amygdala-
120 dmPFC connectivity than women; the degree of amygdala-dmPFC connectivity was inversely correlated
121 with enculturated gender roles such as participants' degree of self-endorsed femininity (Lungu et al.,
122 2015). In a study measuring resting state amygdala connectivity, women showed relatively greater
123 connectivity between amygdala and structures such as the putamen and precuneus, and men showed
124 relatively greater connectivity between amygdala and superior temporal gyrus and inferior frontal gyrus
125 (Engman et al., 2016). Another study found greater amygdala-IFG connectivity in women compared to
126 men (Kogler et al., 2016). In an explicit emotion regulation task involving reappraisal strategy, women
127 and men showed similar levels of self-reported affect following regulation, but women showed less
128 attenuation of amygdala and greater IFG and dlPFC activation (McRae et al., 2008).

129 Although findings of sex differences in structural and functional connectivity have been found
130 elsewhere (e.g., the pars triangularis; see Keresztes et al., 2021 and Rubin et al., 2017), differences of
131 prefrontal-amygdala connectivity appear especially relevant to our investigation of emotion. Therefore,

132 our second hypothesis (H2) is that effective connectivity between amygdala and medial prefrontal
133 regions (ACC, vmPFC) will differ between males and females. To our knowledge, only one study has
134 examined gender differences in effective connectivity of emotion experience, namely using Granger
135 causality analysis (Lungu et al., 2015). In this regard, our DCM analysis of gender makes a novel
136 contribution to the literature.

137 Considering gender differences in emotion and the centrality of culture in socialization, it is
138 worth questioning the persistence of these differences across cultures. Reviewing studies of cross-cultural
139 gender differences in personality, cognitive, and physical traits, Schmitt (2015) showed that most
140 evidence favors explanations implicating an interplay of evolution and sociocultural influences, as
141 opposed to strictly socialization as an explanation. Moreover, he observed a counterintuitive trend
142 wherein more egalitarian cultures show greater sex differences.

143 Studies involving self-report have found culture to interact with gender in their influence on
144 emotion. For instance, Zhao et al. (2019) observed a culture-sex interaction wherein Australian females
145 were uniquely high in self-report empathy, showing greater scores than Mainland Chinese females and
146 Australian males, while no significant difference was found between Australian and Mainland Chinese
147 males. In a follow-up study, Zhao et al. (2021) found the same culture-sex interactions in trait empathy,
148 as well as several interactions in state empathy wherein Australian females showed stronger empathy
149 response than Australian males on several emotion categories. Concerning fear, they found that Chinese
150 female participants scored higher on state empathy than female Australian participants when shown
151 instances of male and female fear, and they scored higher than Chinese male participants for instances of
152 female fear, although they also caution that they had obtained a low empathic accuracy for fear in that
153 study.

154 Bagozzi et al. (1999) found that women's self-reported experience of negative and positive
155 affect was found more likely to embody the norms of their cultures; women from collectivist cultures
156 were more likely to experience positive and negative affect as independent, whereas women from
157 individualist cultures were more likely to experience them as bipolar opposites. Another study spanning
158 37 countries found a robust gender-specific pattern in which women reported more powerless emotions

159 (i.e., fear) than men, but they also found interaction between gender and the country's rated gender
160 equality, such that women from cultures with greater gender equality reported more dominant emotions
161 (i.e., anger) (Fischer et al., 2004). In a task involving explicit emotion regulation in response to negative
162 emotional images, Chinese men and American women reported the lowest and highest levels of emotion,
163 respectively (Davis et al., 2012). Chinese men reported using disengagement strategies to regulate their
164 emotions more than any other group. However, another study found no effect of culture or gender after
165 controlling for depressive symptoms (Kwon et al., 2013).

166 However, neuropsychological investigations of culture-gender interaction and emotion are
167 sparse. Given the past self-report evidence demonstrating culture-sex interaction (Zhao et al., 2019,
168 2021), and ample evidence of culture and gender individually influencing emotion, our third hypothesis
169 (H3) is that gender and culture will likewise be interactive in their influence on the effective connectivity
170 in the brain during fear vs neutral experience.

171

172

2. Method

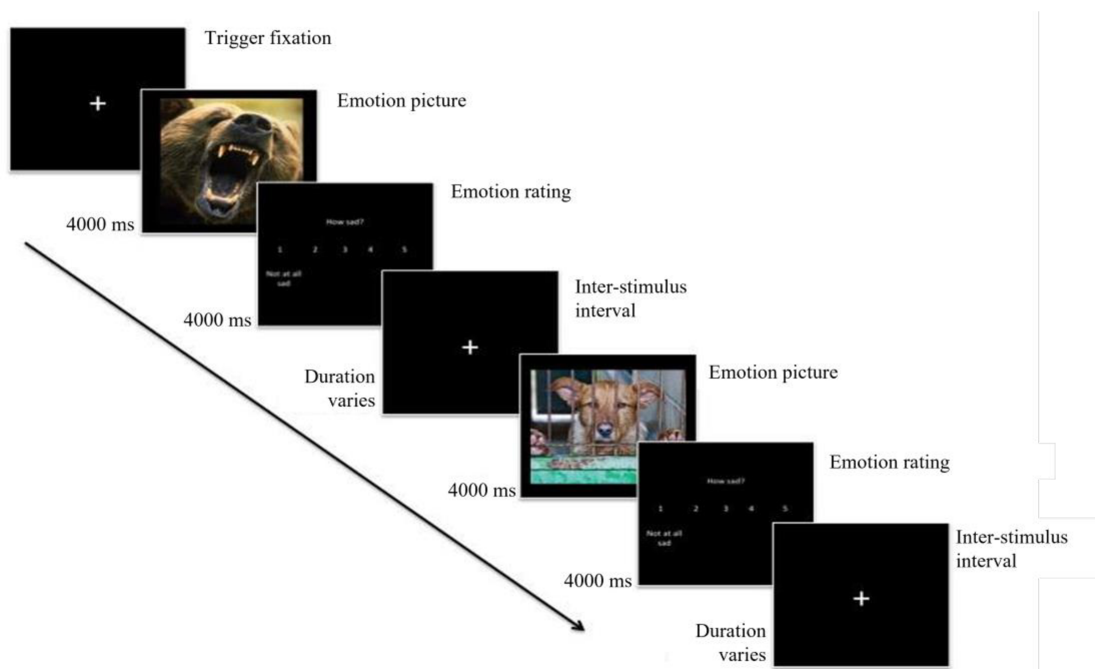
2.1. Participants

174 Twenty-three United States natives of European-American descent (mean \pm SD: 21.2 \pm 1.5 years, 12
175 females) and 13 Chinese natives who had lived in Mainland China for at least 18 years (mean \pm SD: 21.9
176 \pm 2.1 years, seven females) participated in the study. Time lived in Mainland China was included to rule
177 out the possibility of significant enculturation. Gender was evaluated as a dichotomous variable and there
178 were no participants who self-identified a gender different from their biological sex. All participants were
179 native or proficient English-speaking participants who reported having no history of neurological
180 disorder and normal or corrected-to-normal vision. Among Chinese participants, there were no
181 significant gender differences in time lived in China or in the US. All participants were right-handed.
182 Handedness was controlled as it is known to influence brain lateralization (Toga & Thompson, 2003),
183 and hand preference was assessed using the Edinburgh inventory (Oldfield, 1971). Participants provided
184 written informed consent and were given monetary compensation for their participation. The study
185 protocol was approved by the University's Institutional Review Board.

186

187 **2.2 Procedure**

188 This study examined the same EEG dataset as an earlier study implementing Granger causality analysis
 189 on the influence of culture and situation on emotion (Pugh et al., 2021). The image set comprised 180
 190 colored images selected from the International Affective Picture System (Lang et al., 1999). This
 191 included 60 images for each of the emotion categories fear, sad, and neutral. For this study, only neutral
 192 and fear images were examined to obtain a fear-neutral contrast. Sad images were excluded for the
 193 purpose of having a manageable model space. Emotion categorizations were based on normative ratings
 194 obtained from participants on Amazon's Mechanical Turk ($N = 444$; 54% female, $M_{\text{age}} = 37.13$ years, SD
 195 $= 11.48$). For fear images, the average rating for fear was greater than the average rating for the other
 196 emotions. Normative ratings of valence for fear differed significantly from neutral images ($F = 169.51$, p
 197 < 0.001). The arousal level of fear differed significantly from neutral arousal levels ($F = 494.42$, $p <$
 198 0.001).



199

200 **Figure 1** Schematic of stimulus sequence and timing of the task. At the beginning of each trial, cross
 201 fixation was displayed for 4 seconds, followed by an affective picture for 4 seconds, and then emotion
 202 rating scale were presented for 4 seconds. The total duration of each trial was 12 seconds regardless of

203 conditions.

204

205 Images were arranged in five runs, with each run comprising 36 images. Images were presented
206 on a 17" computer screen placed 60 cm in front of the participants. Each image was presented for 4s
207 following a 4s fixation period (Fig. 1). Participants were asked to report their levels of emotion (from 1
208 to 5) after each image presentation.

209 Participants were first presented with a practice trial for task familiarization. Afterwards, an
210 EEG cap was fitted to the participant and the main trials began. After the experiment, participants
211 completed a nine-minute resting state task during which they were asked to focus on the fixation on
212 screen and keep their mind at rest.

213

214 **2.3. EEG Acquisition and Pre-processing**

215 EEG signals were recorded using a 256-electrode EEG cap (Electro-Cap International, Inc.) with 62
216 active electrodes arranged according to the modified 10–20 system (Sharbrough et al., 1991). Recordings
217 were referenced to the left ear lobe and grounded between AFz and Fpz. EEG signals were amplified
218 with g.USBamp amplifiers (g.tec Medical Engineering), sampled at 256 Hz. The EEG data was
219 preprocessed and analyzed using MATLAB (The MathWorks, 2004), EEGLAB (Delorme et al., 2011),
220 and SPM (Litvak et al., 2011). EEG signals were bandpass filtered between 0.01 and 75 Hz to examine
221 only relevant frequency bands. Artifact subspace reconstruction (ASR) was applied to identify and
222 remove artifacts (C. Y. Chang et al., 2018). We performed channel interpolation to reject bad channels as
223 well. The data was then re-referenced to an average reference for further analysis.

224 Following data collection and pre-processing, DCM was implemented in four steps: ROI
225 selection, model specification, parameter estimation, and model comparison. The general procedure of
226 DCM is outlined in Appendix A.

227

228 **2.4 Selection of regions of interest**

229 Five regions of interest (ROIs) were selected based on their functional connectivity at rest (Bickart et al.,

230 2014; Roy et al., 2009) and during instances of fear (Baczkowski et al., 2017; Zhang et al., 2017). As the
231 first ROI, the amygdala bears structural and functional connectivity with regions of the prefrontal cortex
232 (including dlPFC and ACC) (Phillips et al., 2008) and visual cortex (Amaral et al., 2003). It thus serves
233 as a hub to multiple brain networks essential to supporting perception and behavior during affective
234 states (Bickart et al., 2014). Although subcortical areas are not typically the targets of evoked response
235 EEG measures, sources embedded in the limbic area (e.g. amygdala) can be included in a DCM analysis
236 for MEG/EEG model along with other cortical sources, as the interactions between the deep sources and
237 sources close to the scalp can be inferred from DCM (Attal et al., 2012; J. Li et al., 2021).

238 The prefrontal cortex is thought to implicitly regulate amygdala function (Delgado et al., 2008;
239 Diekhof et al., 2011; Gee et al., 2013; Hänsel & von Känel, 2008; Motzkin et al., 2015; Phan et al.,
240 2002), and prefrontal-posterior coupling as measured by EEG is known to be taxed in conditions where
241 different emotion-evoking images are presented (Hao et al., 2019). As a second ROI, the vmPFC was
242 selected for its structural and functional connectivity with the amygdala (Bickart et al., 2014; Phillips et
243 al., 2008; Porrino et al., 1981). As a third ROI, the dlPFC was selected for its role in the central executive
244 network, as well as its role in regulating emotion in tandem with the anterior cingulate cortex (ACC)
245 (MacDonald et al., 2000; Phillips et al., 2008). The dlPFC does not bear strong direct anatomical
246 connections with the amygdala (Delgado et al., 2008; Ray & Zald, 2012), but it has been implicated in
247 tasks of explicit emotion regulation (Banks et al., 2007; de Greck et al., 2012; Morawetz et al., 2016;
248 Ochsner et al., 2002) and may be involved in recruitment of semantic knowledge during the emotion
249 generation and regulation (Lindquist et al., 2012). As a fourth ROI, the ACC bears connections with the
250 amygdala (Bickart et al., 2014), and the dorsal ACC is involved in tasks demanding attention modulation
251 (Hariri et al., 2003). As a fifth ROI, the visual cortex was selected for the nature of our stimuli and its
252 well-known structural connectivity with the amygdala (Amaral et al., 2003). Visual processing is
253 modulated by emotional stimuli (Aguado et al., 2012; Padmala & Pessoa, 2008; Vuilleumier & Driver,
254 2007), and the amygdala has been found to enhance visual encoding of form and motions associated with
255 fearful expressions (Furl et al., 2013).

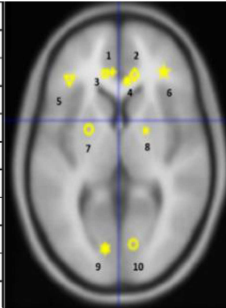
256 ROI coordinates were chosen based on previous studies on fearful emotion modulation for

257 amygdala (Furl et al., 2013), regulatory effect of vmPFC (Motzkin et al., 2015), ACC (Shi et al., 2019),
 258 and dlPFC (Kim et al., 2019). The mean locations for the nodes are listed in Figure 2. Coordinates were
 259 based on the MNI space coordinates for the corresponding region (Lacadie et al., 2008).

260

261

No.	Region	MNI Coordinate
1	l-Amygdala	-24, 0, -21
2	r-Amygdala	21, -1, -22
3	l-ACC	-5, 39, 20
4	r-ACC	6, 33, 16
5	l-vmPFC	-11, 38, -19
6	r-vmPFC	12, 37, -19
7	l-dlPFC	-39, 34, 37
8	r-dlPFC	35, 39, 31
9	l-V1	-11, -81, 7
10	r-V1	11, -78, 9

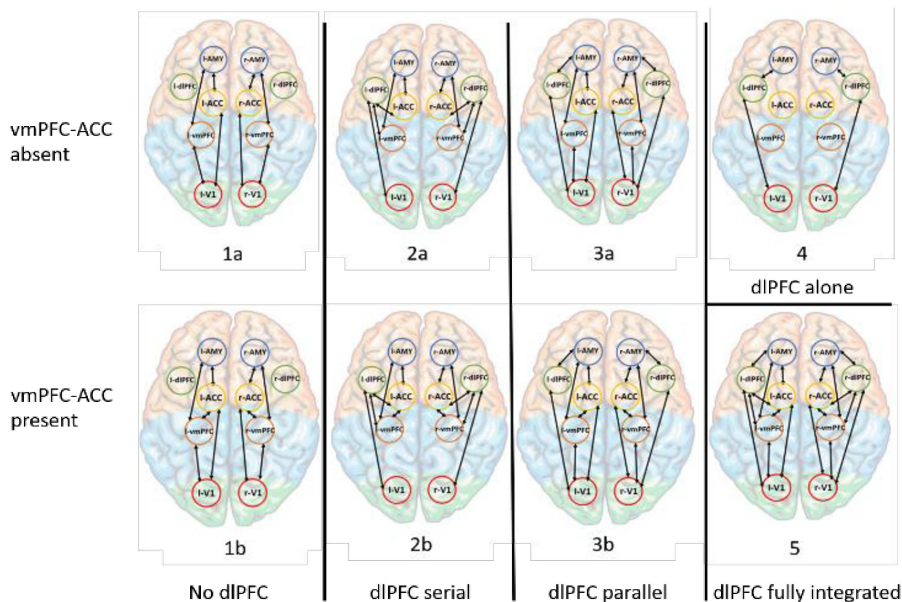


262 **Figure 2** Prior locations for the regions considered for DCM models. Sources of activity were modelled
 263 as equivalent dipoles (estimated posterior moments and locations). Their prior mean locations are
 264 superimposed in an MRI of a standard brain in Montreal Neurological Institute (MNI) space in mm

265

266 2.5 Model specification

267 A model space was created comprising eight models varying in extrinsic connections between the
 268 selected ROIs. Models varied primarily in the manner of connectivity among the dlPFC, vmPFC, and
 269 ACC (Figure 3).



270 Fig. 3. The model space. Double arrow means reciprocal connections. amygdala (AMY); dorsolateral
271 prefrontal cortex (dlPFC); ventromedial prefrontal cortex (vmPFC); anterior cingulate cortex (ACC);
272 primary visual cortex (V1).

273

274 Two models (#1a and #1b) excluded the dlPFC entirely, two models (#2a and #2b) incorporated
275 the dlPFC in serial connection between V1 and the other two frontal regions, two models (#3a and #3b)
276 incorporated the dlPFC as working independently from the ACC and vmPFC, and two models examine
277 two extremes of dlPFC involvement: exclusive involvement of dlPFC (#4) and a dlPFC that is fully
278 integrated with the other frontal regions (#5). The first and second-group models entertain the possibility
279 that the dlPFC affects the amygdala either not at all or indirectly, consistent with findings of
280 neuroanatomical connectivity (Ray & Zald, 2012). Furthermore, within the first, second, and third
281 groupings the models varied in the presence of a vmPFC-ACC connection. In this way, integration of the
282 dlPFC was tested fairly independently of vmPFC-ACC connectivity.

283 As an additional model specification, we adopted Jansen's neural-mass model (Jansen & Rit,
284 1995), which describes each brain source in terms of the average post-membrane potentials and mean
285 firing rates of three neuronal subpopulations corresponding to one of three cortical layers and their
286 mutual inhibitory and excitatory connections.

287

288 **2.6 Parameter estimation**

289 Bayesian model selection (BMS) was used to determine winning models for each group of culture and
290 gender—Chinese, US, females, and males—as well as their factorial combinations. Log-evidence value
291 was used to quantify the model plausibility (Garrido et al., 2007; Penny et al., 2004). The log-evidence
292 indicates which of the pre-established models, or connectivity patterns, best explains the dataset in a
293 manner that is both accurate (due to the accuracy term) and parsimonious (due to the complexity term).
294 For group comparisons log-evidence values are simply summed to obtain a group value. Between two
295 log-evidence values, a difference of at least three is regarded as strong evidence in favor of the winning
296 model (Garrido et al., 2007; Kiebel et al., 2008; Penny et al., 2004). Finally, the average connectivity

297 parameters across models were calculated for estimating the coupling among brain regions using
298 Bayesian model averaging (BMA). BMA is weighted by the posterior probability for each model,
299 meaning that models with greater probability contribute more to the average than models with lower
300 probability.

301 We also examined coupling gains and conditional probabilities for each connection. A coupling gain
302 indicates a directed connection's gain in connectivity in response to exogenous input perturbation (i.e.,
303 experimental stimuli). Higher gains indicate greater gain in connectivity strength, or greater effective
304 connectivity. Positive and negative gains indicate excitatory and inhibitory causal influence, respectively
305 (Friston et al., 2003). A gain is often reported alongside a probability value, indicating the conditional
306 probability of a gain surpassing a threshold value (Garrido et al., 2007).

307

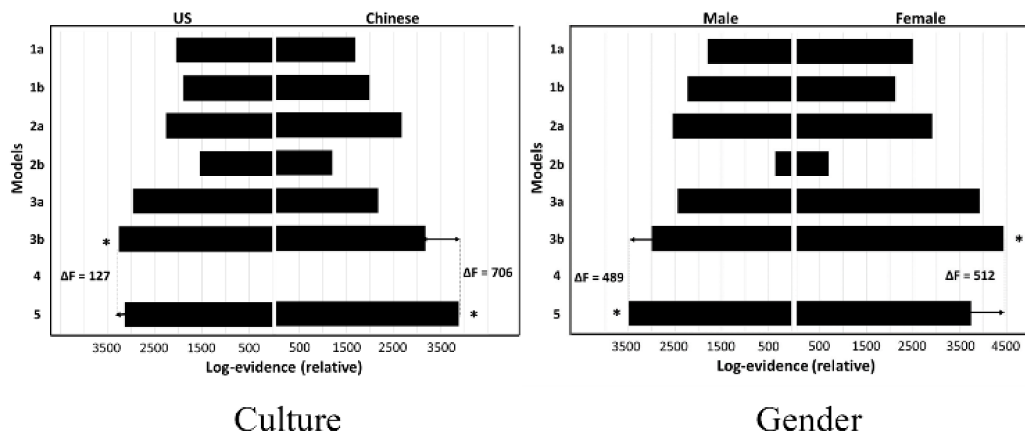
308

3. Results

309 3.1. Winning models

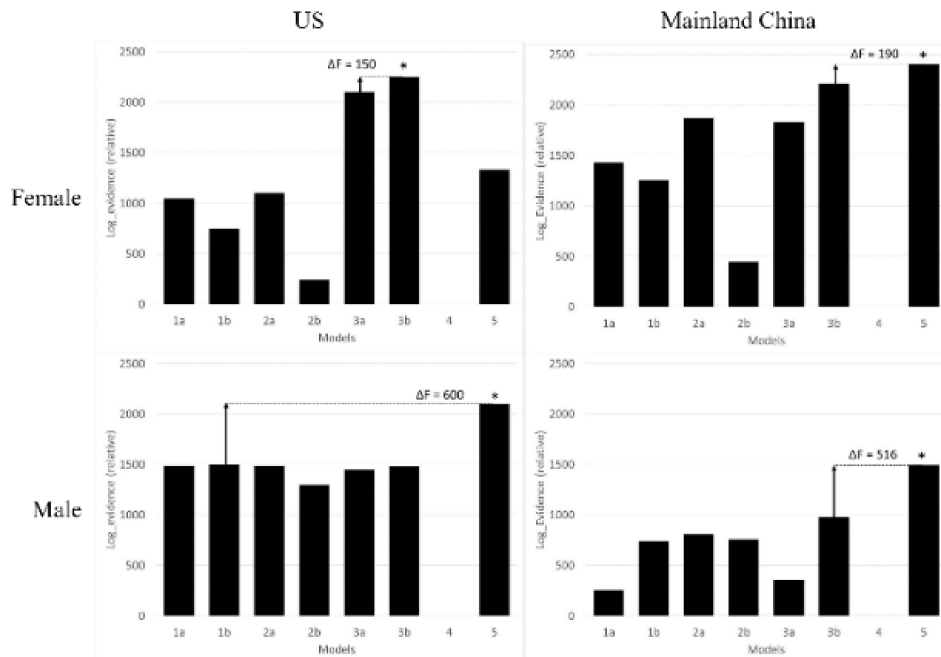
310 Bayesian model selection (BMS) was used to determine winning models for each group of culture and
311 gender. As shown in Figure 4, there were culture-based differences in the winning models. For Chinese
312 participants, the winning model was the one with the fully integrated dlPFC (Model #5), while for US
313 participants the winning model was one in which the dlPFC was relatively less integrated with other
314 cortical structures (Model 3b). The crucial difference between these models is the presence of dlPFC-
315 ACC and dlPFC-vmPFC connections, which are present in #5 and absent in #3b.

316 Differences in evidence between the winning model and the second model were significant for
317 both Chinese participants ($\Delta F = 706$) and US participants ($\Delta F = 127$), although US participants showed
318 an apparently close competition among models #3a, #3b, and #5. Compared to the other two models, #3a
319 is unique in the absence of a vmPFC-ACC connection. That is, all three of these models showed direct
320 dlPFC-amygdala connection, with their only differences being the presence of connections among the
321 frontal regions dlPFC, vmPFC, and ACC.



322

323 Figure 4. Results of Bayesian Model Selection (BMS) for (a) culture and (b) gender groups. The graphs
 324 show an approximation (the free-energy) of log-evidence (i.e. the log of the model evidence). Values are
 325 relative to the model with lowest log-evidence (model #4). Asterisks indicate the winning models in each
 326 group; ΔF indicates differences in log-evidence between the best model and the second optimal model.



327

328 **Figure 5** Results of Bayesian Model Selection (BMS) for each combination of culture and gender on
 329 emotional processing. US-Male ($N = 11$), US-Female ($N = 12$), Chinese-Male ($N = 6$), Chinese-Female

330 ($N = 7$). Asterisks indicate winning models within each group. The graphs show an approximation (the
331 free-energy) of log-evidence (i.e. the log of the model evidence). Values are relative to the model with
332 lowest log-evidence (model #4). Asterisks indicate the winning models in each group; ΔF indicates
333 differences in log-evidence between the best model and the second optimal model.

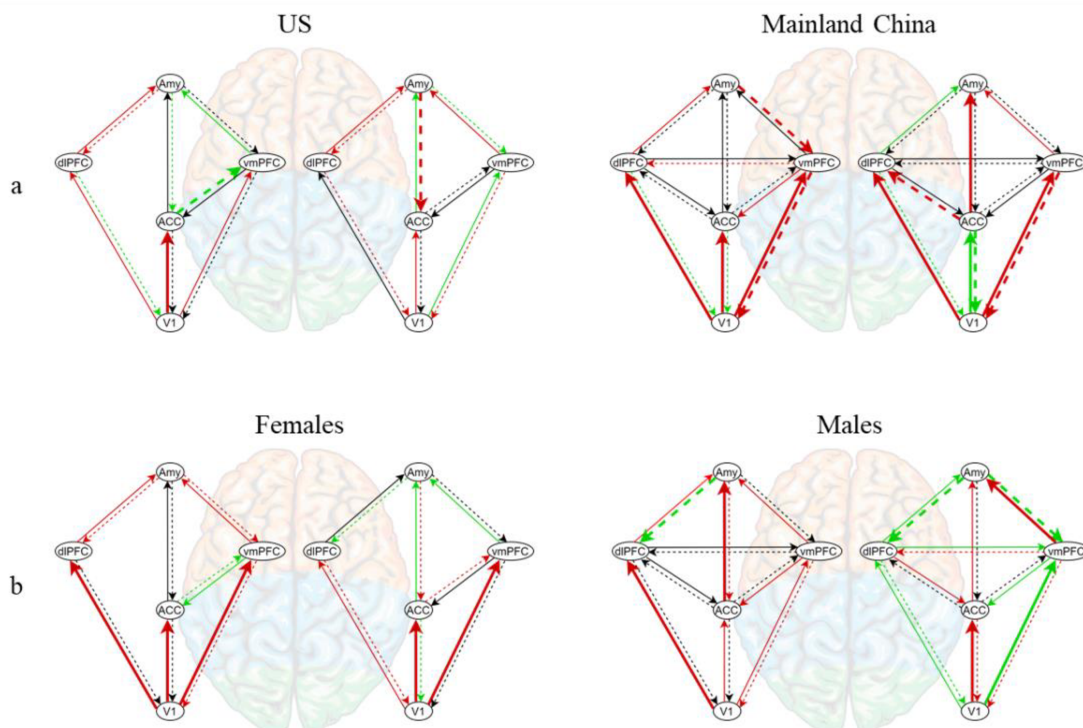
334

335 The winning model for females was the direct-connection model #3b, while that for males was
336 the fully-integrated model #5 (Figure 5). These are the same two winning models as with the culture
337 comparison, with the difference being the presence of dlPFC-vmPFC and dlPFC-ACC connections. Both
338 winning models significantly outperformed their second-place competitors ($\Delta F = 512$ for females, $\Delta F =$
339 489 for males). For females, a close second model was #3a which again is the same as model #3b with
340 the exception of a missing vmPFC-ACC connection. To examine the interaction of culture and gender,
341 we conducted similar BMS procedures for male and female data of Chinese and US participants (Figure
342 6). For Chinese participants, the winning model is the fully integrated model (#5) regardless of gender
343 ($\Delta F = 190$ for females, $\Delta F = 516$ for males); the parallel model (#3b) is a relatively close second place
344 for Chinese females. For US participants, a gender difference was observed with males having the fully
345 integrated model (#5) as winning and females having a parallel model (#3b) as winning. For US females
346 as well, the winning model was marginally higher than model #3a.

347

348 **3.2 Parameter estimates**

349 Using BMA, coupling gains were obtained for the winning model of each group of culture and groups of
350 gender (see Figure 6 for visual summary; see supplementary materials for precise gain values and
351 posterior probabilities). For instance, a gain of .082 from l-amygdala to ACC would indicate an 8.2%
352 increase in effective connectivity fear images, as opposed to neutral images, are presented. To
353 concentrate on non-trivial connections, we focus our attention on gains exceeding 0.1 in value and
354 bearing a posterior probability greater than 0.95 (Bönstrup et al., 2016). This criteria allowed us to reduce
355 our scope of discussion from 64 connections to 15 for the culture comparison, and from 64 connections
356 to 11 for the gender comparison.



357

358 **Figure 6** Significant coupling gains estimated for each connection in the best (or winning) model as a
 359 function of culture (a) and gender (b). Left and right networks correspond to left hemisphere and right
 360 hemisphere, respectively. Color represents coupling gain, or change in effective connectivity in fear vs
 361 neutral conditions ($> 95\%$ posterior probability). Green = significant positive gain; red = significant
 362 negative gain; black = nonsignificant gain. For thicker arrows, coupling gain $\geq .1$; otherwise coupling
 363 gain $< .1$.

364

365 Because of differences in winning models for culture and gender, comparisons of their coupling
 366 gains cannot be made. Likewise, culture-gender interaction shows a unique winning model for US
 367 females, and this precludes a comparison of this group's parameters with other groups. However,
 368 comparisons of groups bearing model 5 is still feasible; this includes Chinese females, Chinese males,
 369 and US males.

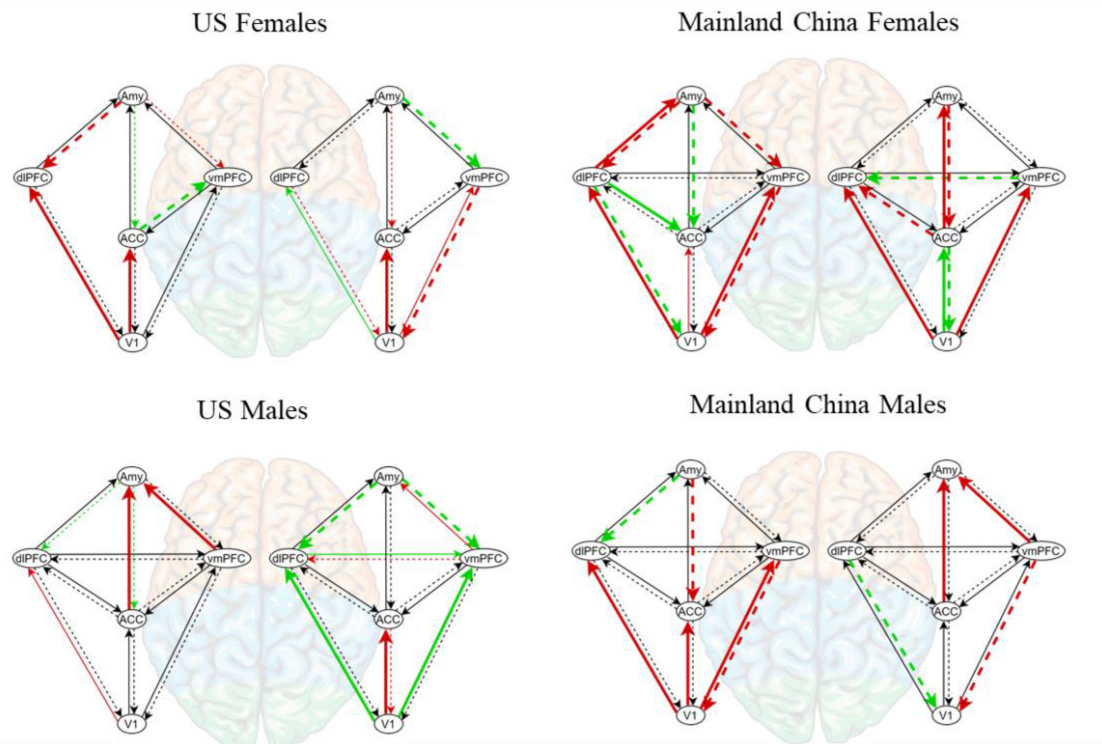
370

371 Figure 7 shows coupling gains and posterior probabilities for the factorial combinations of
 372 culture and gender. For groups bearing model 5, Chinese females showed the largest number of strong
 connections (18), followed by Chinese males (13) and US and males (7). Coupling gains from the

373 amygdala were especially strong for the Chinese female group; of the six connections, four were strong
374 and significant (to l-ACC = 0.126, r-ACC = -0.133, l-vmPFC = -0.196, l-dIPFC = -0.147). For
375 connections to the amygdala, Chinese males exhibited strong connectivity to the right amygdala from all
376 three frontal regions, though only two were significant (from ACC = -0.171, vmPFC = -0.205).
377 Correspondingly, Chinese females showed strong connection to the amygdala from r-ACC-amygdala (-
378 0.154) and l-dIPFC-amygdala (-0.145). US males showed strong connections to the left amygdala from l-
379 ACC (-0.175) and l-vmPFC (-0.126).

380 For connections from the dIPFC, Chinese females showed strong connections to l-amygdala (-
381 0.145), l-ACC (0.154), and l-V1 (0.149). Chinese males showed strong connection from r-dIPFC to r-
382 amygdala (0.106) and r-V1 (0.205), though the former connection fell short of significant. US males did
383 not show strong connections to or from the dIPFC. Chinese females showed strong significant
384 connections to l-dIPFC (from l-amygdala = -0.147, l-V1 = -0.348, r-V1 = -0.349) and to r-dIPFC (from r-
385 ACC = -0.136, r-vmPFC = 0.103).

386 For connections with V1, Chinese females showed the greatest number of strong from-V1
387 connections (5). Strong connections to V1 were most frequent in both Chinese males (3) and females (3).
388 US males showed no strong to-V1 connection.



389

390 **Figure 7** Significant coupling gains estimated for each connection in the best (or winning) model of each
 391 culture-gender pairing. Left and right networks correspond to left hemisphere and right hemisphere,
 392 respectively. Color represents coupling gain, or change in effective connectivity in fear vs neutral
 393 conditions (> 95% posterior probability). Green = significant positive gain; red = significant negative
 394 gain; black = nonsignificant gain. For thicker arrows, gain $\geq .1$; otherwise gain $< .1$.

395

396

4. Discussion

397

398

399

400

401

402

403

404

The purpose of this study was to examine the role of cultural background and gender on emotion
 experience in terms of effective connectivity among a set of brain regions consistently linked to
 emotions. To this end, we applied DCM to EEG data, leveraging advantages of high temporal resolution
 that could not be offered by other imaging methods. Consistent with previous studies, our results
 confirmed that fear is associated with effective connectivity amongst prefrontal, amygdala, and occipital
 regions. Consistent with a constructionist account, we also demonstrated for the first time that this
 effective connectivity is modulated by participants' culture of origin and gender, as well as an interaction
 between the two. We discuss these findings in further detail, beginning with the interaction effect of

405 culture and gender, pertaining to H3.

406

407 **4.1 Interaction of culture and gender on connectivity during fearful experiences**

408 Our main expectation (H3) was that culture and gender would interact to influence effective connectivity,
409 and this was confirmed with a finding that US female group exclusively showed a winning model that
410 did not bear dlPFC-vmPFC or dlPFC-ACC connections. That is, US females were differentially affected
411 as a function of their gender and cultural background, with US males, Chinese females, and Chinese
412 males bearing a common winning model wherein the these connections were present.

413 Though the count of significant connections is too granular for a quantitative statistical analysis,
414 it is worth noting that Chinese females showed the greatest number of strong connections, followed by
415 Chinese males. One notable difference concerned coupling gains from the amygdala, which was more
416 consistently negative for Chinese females compared to Chinese males and US males. As an additional
417 follow-up analysis for groups bearing model 5 as the winning model, we compared the amy-dlPFC and
418 dlPFC-amy coupling gains between Chinese females and Chinese males, and between Chinese males and
419 US males (Figure 8). Our post-hoc test revealed a significant difference between these Chinese females
420 and Chinese males in the amy-dlPFC connectivity strength ($t(16) = -5.65, p < .001$). This was unexpected
421 considering the effect of gender, wherein females overall showed a winning model without a dlPFC-
422 amygdala connection. A second difference was a consistent negative couplings in connections to the
423 dlPFC from bilateral amygdala, bilateral V1, and r-ACC in Chinese females, while in Chinese males
424 these gains were more heterogeneous.

425 Altogether, US females were markedly different from the other four groups in the relative
426 absence of two connections in their winning model. Chinese females demonstrated the strongest response
427 to fear images, and they alone showed strong inhibitory connection from the dlPFC to the amygdala in
428 either hemisphere. This is reminiscent of a finding in an earlier study that women of eastern and western
429 cultures occupied extremes in terms of self-reported affective experiences, with females aligning most
430 strongly with their culture, while males were less extremely different (Bagozzi et al., 1999). Insofar as
431 dlPFC connectivity could reflect automatic regulation, Chinese females align most strongly with a

432 cultural drive to regulate emotion, while US females do not. Additionally, gender differences in the l-
433 amygdala-dlPFC were found across culture, with gains that are positive gains for males and negative
434 gains for females. Given that the reverse connection was not significantly different across cultural
435 groups, it is possible that this difference reflects differences between males and females in the
436 amygdala's role in directing attention.

437

438 **4.2 Effect of culture on connectivity during fearful experiences**

439 Regarding culture, our hypothesis (H1) was that Chinese participants would demonstrate greater
440 involvement of prefrontal regions compared to US participants. This was confirmed by the finding of
441 cultural differences in winning models (Fig. 4). Chinese participants had the fully integrated dlPFC
442 model (#5) as their winning model bearing dlPFC-vmPFC and dlPFC-ACC connections, while US
443 participants had a parallel connection model (#3b) in which dlPFC was not connected to ACC and
444 vmPFC as their winning model.

445 Thus, for Chinese participants, the dlPFC appears to be more strongly affected in its
446 connectivity with other regions during the experience of fear. An interesting point is that for all groups,
447 the winning model bore a direct connection in effective connectivity between the dlPFC and the
448 amygdala, despite a known lack of anatomical connection between the two regions (Ray & Zald, 2012).
449 One possibility is that dlPFC exerts effects on amygdala via other regions we did not examine. Either
450 way, for US participants alone the dlPFC appears to have had effective connectivity with amygdala in the
451 absence of simultaneous vmPFC and ACC connectivity.

452 A common explanation for cultural differences in emotion regulation has been that the
453 collectivist aspect of Eastern cultures more strongly encourages group conformity, which entails
454 regulating one's own emotions (Butler et al., 2007; de Greck et al., 2012; Lindquist & Barrett, 2008; Park
455 & Huang, 2010). The constructionist account of emotion holds that emotion is an emergent product of
456 interactions between networks responsible for creating visceromotor states in the service of adaptive
457 responses (in this case, the amygdala) and networks responsible for interpreting stimuli and bodily input
458 in terms of semantic knowledge (i.e., the conceptualization network) (Barrett, 2011). Differences of

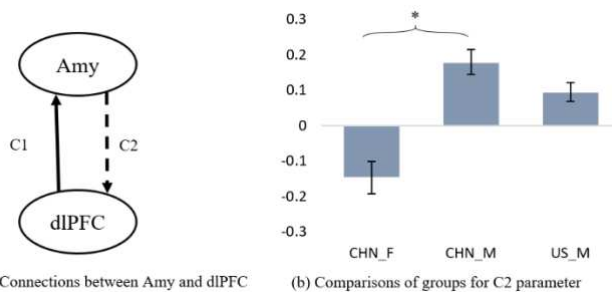
459 culture include both semantic knowledge of emotion-laden concepts and selection of appropriate
 460 responses. Such differences would likely manifest themselves as differences in brain regions supporting
 461 the representation and use of conceptual knowledge as well as the selection of behavioral responses, such
 462 as the vmPFC, ACC and dlPFC. Insofar as these regions also project to the visual cortex (Barrett & Bar,
 463 2009), differences in conceptualization could influence predictions about the meaning of visual stimuli.

464 Altogether, BMS established connectivity differences between Chinese and US participants in
 465 terms of winning models, while differences in amygdala-dlPFC connectivity strengths could not be
 466 compared due to differences in winning models. Future research should examine in greater detail the
 467 specific mechanisms underlying differences of amygdala-dlPFC connectivity.

468

469 4.3 Effect of gender on connectivity during fearful experiences

470 We also expected (H2) that males, compared to females, would show differences in connectivity between
 471 medial frontal regions (ACC, vmPFC) and amygdala, based on previous research showing greater
 472 functional connectivity between dmPFC and amygdala in males. However, while males and females
 473 differed in their winning models for connectivity, they both favored models bearing all three connections
 474 to the amygdala. The key difference between the models involved dlPFC-vmPFC and dlPFC-ACC
 475 connections, which were present in the male group's winning model and absent in the female group's
 476 winning model. This suggests that for females the dlPFC had less of an influence to and from both ACC
 477 and vmPFC. Future research might examine these unexpected differences.



478 Figure 8 Coupling gains obtained by Bayesian model averaging are graphed for (a) C2 connection from
 479 Amy to dlPFC at LH by (b) comparison of C2 for groups bearing model 5 as the winning model. * $p <$
 480 .005. LH, left hemisphere; dlPFC, dorsolateral prefrontal cortex; Amy, amygdala. Note that US_F group

481 is not included, as their winning model was different from the other three groups and thus prevented
482 valid comparison.

483

484 **4.4 Implications for affective computing**

485 Beyond implications for neuropsychology, there are a couple of implications for affective computing, the
486 design of human-computer interaction systems capable of inferring human emotion from facial
487 expression and other biological and behavioral measures (Poria et al., 2017). Analyses of EEG-measured
488 connectivity and activation patterns show promise in categorizing emotion (P. Li et al., 2019). As a
489 means of analyzing effective connections, the prospect of applying DCM to emotion classification
490 systems is a prospect worth exploring. A second implication is that, while much of the emotion
491 recognition efforts has leaned toward a one-size-fits-all approach to emotion recognition (Picard, 2003;
492 Poria et al., 2017), the evidence presented here converges with earlier evidence from neuropsychology
493 and social psychology in support of the account that emotion is constructed in a manner highly bound to
494 individual traits, namely, cultural background and gender. Classification accuracy has already been
495 shown to improve when accounting for gender (Rukavina et al., 2013; Vogt & André, 2006) and age
496 (Rukavina et al., 2016). The prospect of incorporating culture in classification systems is also worth
497 exploring.

498

499 **4.5 Limitations**

500 We acknowledge a limitation of sample size; however, previous DCM studies have demonstrated strong
501 effects examining comparably small sample sizes (Huang et al., 2021; Kim et al., 2017, 2019; Protopapa
502 et al., 2014; Sato et al., 2001), and our sample proved sufficient to establish significance among many
503 connections. Previous DCM studies have likewise shown uneven sample sizes (e.g., Cooray et al., 2016).
504 In terms of technical limitations, a 64-channel analysis is relatively coarse compared to analyses
505 employing more channels. However, previous DCM research has proved successful in using this number
506 of channels (Babajani-Feremi et al., 2012; Legon et al., 2016). As another limitation, DCM does not
507 allow the comparison of parameters across different winning models, and this prevented a more thorough

508 analysis of culture-gender interaction. Future studies should further examine the fronto-limbic
509 connections implicated in the winning model differences.

510 We also acknowledge limitations in our operationalization of culture and gender. There is the
511 question of cultural representativeness, given that the recruitment of Mainland Chinese participants living
512 in the US raises the question of possible enculturation. Our recruiting criteria aimed at discounting this
513 possibility, but a more controlled method would have been to recruit participants in their home countries.
514 We also categorized participants based on self-reported gender since gendered socialization is a form of
515 enculturation. While gender is non-binary and norms in the field are beginning to shift, our study still
516 reflects the present norms in the field (Abbruzzese et al., 2019; Keresztes et al., 2021). Lastly, a
517 limitation of scope was imposed by a need for tractability, and so not every emotion-relevant region of
518 the brain was examined, and moreover only one emotion category in our paradigm was examined. For
519 instance, future work might examine the pars triangularis, which was recently implicated studies
520 examining sexual dimorphism in structural connectivity (Keresztes et al., 2021) and sex differences in
521 the influence of hormones (Rubin et al., 2017). Nevertheless, our application of DCM was fruitful in
522 helping to clarify the hierarchical relationships between brain regions in negative emotion modulation
523 among people from different cultural backgrounds and of different gender. It provides a basis for future
524 development and improvement in understanding the social-biological loop of human information
525 processing.

526

527

5. Conclusion

528 To summarize, we investigated the influence of culture and gender on emotion—specifically fear—by
529 measuring the effective connectivity among brain regions of a frontal-limbic-amygdala-visual network.

530 We found that connections among prefrontal regions—and in particular with the dlPFC—vary across
531 culture and gender, with Chinese females showing especially strong connectivity from the amygdala to
532 frontal regions and US females favoring a model with relatively sparse integration of the dlPFC with
533 other frontal regions. These results provide further support for an approach that accounts for the situated
534 nature of emotion. To our knowledge, this is also the first investigation of culture-gender interaction

535 through the lens of EEG and effective connectivity via the DCM method.

536

537 **Acknowledgments**

538 This research was partly supported by the National Science Foundation (NSF) under Grant NSF BCS-
539 1551688. Any opinions, findings, and conclusions or recommendations expressed in this material are
540 those of the authors and do not necessarily reflect the views of the NSF.

References

- 541
542 Abbruzzese, L., Magnani, N., Robertson, I. H., & Mancuso, M. (2019). Age and gender differences in
543 emotion recognition. *Frontiers in Psychology, 10*(OCT). <https://doi.org/10.3389/fpsyg.2019.02371>
- 544 Adolphs, R. (2008). Fear, faces, and the human amygdala. *Current Opinion in Neurobiology, 18*(2), 166–
545 172. <https://doi.org/10.1016/j.conb.2008.06.006>
- 546 Aguado, L., Valdés-Conroy, B., Rodríguez, S., Román, F. J., Diéguez-Risco, T., & Fernández-Cahill, M.
547 (2012). Modulation of early perceptual processing by emotional expression and acquired valence
548 of faces: An ERP study. *Journal of Psychophysiology, 26*(1), 29–41. [https://doi.org/10.1027/0269-](https://doi.org/10.1027/0269-8803/a000065)
549 [8803/a000065](https://doi.org/10.1027/0269-8803/a000065)
- 550 Amaral, D. ., Behnia, H., & Kelly, J. . (2003). Topographic organization of projections from the
551 amygdala to the visual cortex in the macaque monkey. *Neuroscience, 118*(4), 1099–1120.
552 [https://doi.org/10.1016/S0306-4522\(02\)01001-1](https://doi.org/10.1016/S0306-4522(02)01001-1)
- 553 Andreano, J. M., Dickerson, B. C., & Feldman Barrett, L. (2014). Sex differences in the persistence of
554 the amygdala response to negative material. *Social Cognitive and Affective Neuroscience, 9*(9),
555 1388–1394. <https://doi.org/10.1093/scan/nst127>
- 556 Attal, Y., Maess, B., Friederici, A., & David, O. (2012). Head models and dynamic causal modeling of
557 subcortical activity using magnetoencephalographic/electroencephalographic data. *Reviews in the*
558 *Neurosciences, 23*(1). <https://doi.org/10.1515/rns.2011.056>
- 559 Babajani-Feremi, A., Gumenyuk, V., Roth, T., Drake, C. L., & Soltanian-Zadeh, H. (2012). Connectivity
560 analysis of novelty process in habitual short sleepers. *NeuroImage, 63*(3), 1001–1010.
561 <https://doi.org/10.1016/j.neuroimage.2012.08.011>
- 562 Baczkowski, B. M., Johnstone, T., Walter, H., Erk, S., & Veer, I. M. (2017). Sliding-window analysis
563 tracks fluctuations in amygdala functional connectivity associated with physiological arousal and
564 vigilance during fear conditioning. *NeuroImage, 153*, 168–178.
565 <https://doi.org/10.1016/j.neuroimage.2017.03.022>
- 566 Bagozzi, R. P., Wong, N., & Yi, Y. (1999). The Role of Culture and Gender in the Relationship between
567 Positive and Negative Affect. *Cognition & Emotion, 13*(6), 641–672.

- 568 <https://doi.org/10.1080/026999399379023>
- 569 Banks, S. J., Eddy, K. T., Angstadt, M., Nathan, P. J., & Luan Phan, K. (2007). Amygdala-frontal
570 connectivity during emotion regulation. *Social Cognitive and Affective Neuroscience*, 2(4), 303–
571 312. <https://doi.org/10.1093/scan/nsm029>
- 572 Barrett, L. F. (2011). Constructing Emotion. In *Psychological Topics* (Vol. 20). Lindquist & Barrett.
- 573 Barrett, L. F. (2017). The theory of constructed emotion: an active inference account of interoception and
574 categorization. *Social Cognitive and Affective Neuroscience*, 12(1), 1–23.
575 <https://doi.org/10.1093/scan/nsw154>
- 576 Barrett, L. F., & Bar, M. (2009). See it with feeling: affective predictions during object perception.
577 *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1521), 1325–1334.
578 <https://doi.org/10.1098/rstb.2008.0312>
- 579 Barrett, L. F., & Satpute, A. B. (2013). Large-scale brain networks in affective and social neuroscience:
580 towards an integrative functional architecture of the brain. *Current Opinion in Neurobiology*.
581 <http://www.ncbi.nlm.nih.gov/pubmed/23352202>
- 582 Bickart, K. C., Dickerson, B. C., & Barrett, L. F. (2014). The amygdala as a hub in brain networks that
583 support social life. *Neuropsychologia*, 63, 235–248.
584 <https://doi.org/10.1016/j.neuropsychologia.2014.08.013>
- 585 Bonassi, A., Ghilardi, T., Gabrieli, G., Truzzi, A., Doi, H., Borelli, J. L., Lepri, B., Shinohara, K., &
586 Esposito, G. (2021). The recognition of cross-cultural emotional faces is affected by intensity and
587 ethnicity in a Japanese sample. *Behavioral Sciences*, 11(5), 1–19.
588 <https://doi.org/10.3390/bs11050059>
- 589 Bönstrup, M., Schulz, R., Feldheim, J., Hummel, F. C., & Gerloff, C. (2016). Dynamic causal modelling
590 of EEG and fMRI to characterize network architectures in a simple motor task. *NeuroImage*, 124,
591 498–508. <https://doi.org/10.1016/j.neuroimage.2015.08.052>
- 592 Brooks, J. A., Shablack, H., Gendron, M., Satpute, A. B., Parrish, M. H., & Lindquist, K. A. (2016). The
593 role of language in the experience and perception of emotion: a neuroimaging meta-analysis. *Social
594 Cognitive and Affective Neuroscience*, nsw121. <https://doi.org/10.1093/scan/nsw121>

- 595 Brown, H. R., & Friston, K. J. (2012). Dynamic causal modelling of precision and synaptic gain in visual
596 perception — an EEG study. *NeuroImage*, 63(1), 223–231.
597 <https://doi.org/10.1016/j.neuroimage.2012.06.044>
- 598 Butler, E. A., Lee, T. L., & Gross, J. J. (2007). Emotion regulation and culture: Are the social
599 consequences of emotion suppression culture-specific? *Emotion*, 7(1), 30–48.
600 <https://doi.org/10.1037/1528-3542.7.1.30>
- 601 Chang, C. Y., Hsu, S.-H., Pion-Tonachini, L., & Jung, T.-P. (2018). Evaluation of Artifact Subspace
602 Reconstruction for Automatic EEG Artifact Removal. *2018 40th Annual International Conference
603 of the IEEE Engineering in Medicine and Biology Society (EMBC)*, 1242–1245.
604 <https://doi.org/10.1109/EMBC.2018.8512547>
- 605 Chang, Y.-P., & Algoe, S. B. (2020). On thanksgiving: Cultural variation in gratitude demonstrations and
606 perceptions between the United States and Taiwan. *Emotion*, 20(7), 1185–1205.
607 <https://doi.org/10.1037/emo0000662>
- 608 Chiao, J. Y., Cheon, B. K., Pornpattananankul, N., Mrazek, A. J., & Blizinsky, K. D. (2013). Cultural
609 Neuroscience: Progress and Promise. *Psychological Inquiry*, 24(1), 1–19.
610 <https://doi.org/10.1080/1047840X.2013.752715>
- 611 Coifman, K. G., Flynn, J. J., & Pinto, L. A. (2016). When context matters: Negative emotions predict
612 psychological health and adjustment. *Motivation and Emotion*, 40(4), 602–624.
613 <https://doi.org/10.1007/s11031-016-9553-y>
- 614 Cooray, G. K., Garrido, M. I., Brismar, T., & Hyllienmark, L. (2016). The maturation of mismatch
615 negativity networks in normal adolescence. *Clinical Neurophysiology*, 127(1), 520–529.
616 <https://doi.org/10.1016/j.clinph.2015.06.026>
- 617 Cunningham, W. A., Dunfield, K. A., & Stillman, P. E. (2013). Emotional States from Affective
618 Dynamics. *Emotion Review*, 5(4), 344–355. <https://doi.org/10.1177/1754073913489749>
- 619 Davis, E., Greenberger, E., Charles, S., Chen, C., Zhao, L., & Dong, Q. (2012). Emotion experience and
620 regulation in China and the United States: How do culture and gender shape emotion responding?
621 *International Journal of Psychology*, 47(3), 230–239.

- 622 <https://doi.org/10.1080/00207594.2011.626043>
- 623 de Greck, M., Shi, Z., Wang, G., Zuo, X., Yang, X., Wang, X., Northoff, G., & Han, S. (2012). Culture
624 modulates brain activity during empathy with anger. *NeuroImage*, *59*(3), 2871–2882.
625 <https://doi.org/10.1016/j.neuroimage.2011.09.052>
- 626 Delgado, M. R., Nearing, K. I., LeDoux, J. E., & Phelps, E. A. (2008). Neural Circuitry Underlying the
627 Regulation of Conditioned Fear and Its Relation to Extinction. *Neuron*, *59*(5), 829–838.
628 <https://doi.org/10.1016/j.neuron.2008.06.029>
- 629 Delorme, A., Mullen, T., Kothe, C., Akalin Acar, Z., Bigdely-Shamlo, N., Vankov, A., & Makeig, S.
630 (2011). EEGLAB, SIFT, NFT, BCILAB, and ERICA: New tools for advanced EEG processing.
631 *Computational Intelligence and Neuroscience*. <https://doi.org/10.1155/2011/130714>
- 632 Diekhof, E. K., Geier, K., Falkai, P., & Gruber, O. (2011). Fear is only as deep as the mind allows. A
633 coordinate-based meta-analysis of neuroimaging studies on the regulation of negative affect.
634 *NeuroImage*, *58*(1), 275–285. <https://doi.org/10.1016/j.neuroimage.2011.05.073>
- 635 Eagly, A. H. (2013). *Sex Differences in Social Behavior*. Psychology Press.
636 <https://doi.org/10.4324/9780203781906>
- 637 Ellsworth, P. C. (2013). Appraisal Theory: Old and New Questions. *Emotion Review*, *5*(2), 125–131.
638 <https://doi.org/10.1177/1754073912463617>
- 639 Engman, J., Linnman, C., Van Dijk, K. R. A., & Milad, M. R. (2016). Amygdala subnuclei resting-state
640 functional connectivity sex and estrogen differences. *Psychoneuroendocrinology*, *63*, 34–42.
641 <https://doi.org/10.1016/j.psyneuen.2015.09.012>
- 642 Fischer, A. H., Rodriguez Mosquera, P. M., Van Vianen, A. E. M., & Manstead, A. S. R. (2004). Gender
643 and Culture Differences in Emotion. *Emotion*, *4*(1), 87–94. <https://doi.org/10.1037/1528-3542.4.1.87>
- 644
- 645 Friston, K. J., Harrison, L., & Penny, W. (2003). Dynamic causal modelling. *NeuroImage*, *19*(4), 1273–
646 1302. [https://doi.org/10.1016/S1053-8119\(03\)00202-7](https://doi.org/10.1016/S1053-8119(03)00202-7)
- 647 Fujita, F., Diener, E., & Sandvik, E. (1991). *PERSONALITY PROCESSES AND INDIVIDUAL*
648 *DIFFERENCES Gender Differences in Negative Affect and Well-Being: The Case for Emotional*

- 649 *Intensity*.
- 650 Furl, N., Henson, R. N., Friston, K. J., & Calder, A. J. (2013). Top-down control of visual responses to
651 fear by the amygdala. *Journal of Neuroscience*, 33(44), 17435–17443.
652 <https://doi.org/10.1523/JNEUROSCI.2992-13.2013>
- 653 Garrido, M. I., Kilner, J. M., Kiebel, S. J., Stephan, K. E., & Friston, K. J. (2007). Dynamic causal
654 modelling of evoked potentials: A reproducibility study. *NeuroImage*, 36(3), 571–580.
655 <https://doi.org/10.1016/j.neuroimage.2007.03.014>
- 656 Gee, D. G., Gabard-Durnam, L. J., Flannery, J., Goff, B., Humphreys, K. L., Telzer, E. H., Hare, T. A.,
657 Bookheimer, S. Y., & Tottenham, N. (2013). Early developmental emergence of human amygdala-
658 prefrontal connectivity after maternal deprivation. *Proceedings of the National Academy of*
659 *Sciences*, 110(39), 15638–15643. <https://doi.org/10.1073/pnas.1307893110>
- 660 Gelfand, M. J., Harrington, J. R., & Jackson, J. C. (2017). The Strength of Social Norms Across Human
661 Groups. *Perspectives on Psychological Science*. <https://doi.org/10.1177/1745691617708631>
- 662 Gendron, M. (2017). Revisiting diversity: cultural variation reveals the constructed nature of emotion
663 perception. In *Current Opinion in Psychology* (Vol. 17, pp. 145–150). Elsevier B.V.
664 <https://doi.org/10.1016/j.copsyc.2017.07.014>
- 665 Gevins, A. (1997). High-resolution EEG mapping of cortical activation related to working memory:
666 effects of task difficulty, type of processing, and practice. *Cerebral Cortex*, 7(4), 374–385.
667 <https://doi.org/10.1093/cercor/7.4.374>
- 668 Guarnaccia, P. J., DeLaCancela, V., & Carrillo, E. (1989). The multiple meanings of ataques de nervios
669 in the Latino community. *Medical Anthropology*, 11(1), 47–62.
670 <https://doi.org/10.1080/01459740.1989.9965981>
- 671 Han, S., & Ma, Y. (2014). Cultural differences in human brain activity: A quantitative meta-analysis.
672 *NeuroImage*, 99, 293–300. <https://doi.org/10.1016/j.neuroimage.2014.05.062>
- 673 Hänsel, A., & von Känel, R. (2008). The ventro-medial prefrontal cortex: A major link between the
674 autonomic nervous system, regulation of emotion, and stress reactivity? In *BioPsychoSocial*
675 *Medicine* (Vol. 2). <https://doi.org/10.1186/1751-0759-2-21>

- 676 Hao, Y., Yao, L., Smith, D. M., Sorel, E., Anderson, A. K., Schumacher, E. H., & Evans, G. W. (2019).
677 Prefrontal-posterior coupling mediates transitions between emotional states and influences
678 executive functioning. *Scientific Reports*, *9*(1), 1–9. <https://doi.org/10.1038/s41598-019-44624-2>
- 679 Hariri, A. R., Mattay, V. S., Tessitore, A., Fera, F., & Weinberger, D. R. (2003). *Neocortical Modulation*
680 *of the Amygdala Response to Fearful Stimuli*. [https://doi.org/10.1016/S0002-3223\(03\)01786-9](https://doi.org/10.1016/S0002-3223(03)01786-9)
- 681 Huang, J., Choo, S., Pugh, Z. H., & Nam, C. S. (2021). Evaluating Effective Connectivity of Trust in
682 Human–Automation Interaction: A Dynamic Causal Modeling (DCM) Study. *Human Factors: The*
683 *Journal of the Human Factors and Ergonomics Society*, 001872082098744.
684 <https://doi.org/10.1177/0018720820987443>
- 685 Huang, J., & Nam, C. S. (2020). Dynamic Causal Modeling Approach to Neuroergonomics. In C. S.
686 Nam (Ed.), *Neuroergonomics: Principles and Practices*. Springer.
- 687 Jackson, J. C., Watts, J., Henry, T. R., List, J.-M., Forkel, R., Mucha, P. J., Greenhill, S. J., Gray, R. D.,
688 & Lindquist, K. A. (2019). Emotion semantics show both cultural variation and universal structure.
689 *Science*, *366*(6472), 1517–1522. <https://doi.org/10.1126/science.aaw8160>
- 690 Jansen, B. H., & Rit, V. G. (1995). Electroencephalogram and visual evoked potential generation in a
691 mathematical model of coupled cortical columns. *Biological Cybernetics*, *73*(4), 357–366.
692 <https://doi.org/10.1007/BF00199471>
- 693 Keresztes, L., Szögi, E., Varga, B., & Grolmusz, V. (2021). Identifying super-feminine, super-masculine
694 and sex-defining connections in the human brain graph. *Cognitive Neurodynamics*, *15*(6), 949–959.
695 <https://doi.org/10.1007/s11571-021-09687-w>
- 696 Kiebel, S. J., Garrido, M. I., Moran, R. J., & Friston, K. J. (2008). Dynamic causal modelling for EEG
697 and MEG. *Cognitive Neurodynamics*, *2*(2), 121–136. <https://doi.org/10.1007/s11571-008-9038-0>
- 698 Kim, N. Y., House, R., Yun, M. H., & Nam, C. S. (2019). Neural Correlates of Workload Transition in
699 Multitasking: An ACT-R Model of Hysteresis Effect. *Frontiers in Human Neuroscience*, *12*.
700 <https://doi.org/10.3389/fnhum.2018.00535>
- 701 Kim, N. Y., Wittenberg, E., & Nam, C. S. (2017). Behavioral and Neural Correlates of Executive
702 Function: Interplay between Inhibition and Updating Processes. *Frontiers in Neuroscience*,

- 703 11(JUN), 1–14. <https://doi.org/10.3389/fnins.2017.00378>
- 704 Kleinknecht, R. A., Dinnel, D. L., Kleinknecht, E. E., Hiruma, N., & Harada, N. (1997). Cultural factors
705 in social anxiety: A comparison of social phobia symptoms and Taijin Kyofusho. *Journal of*
706 *Anxiety Disorders*, 11(2), 157–177. [https://doi.org/10.1016/S0887-6185\(97\)00004-2](https://doi.org/10.1016/S0887-6185(97)00004-2)
- 707 Knyazev, G. G., Slobodskoj-Plusnin, J. Y., & Bocharov, A. V. (2010). Gender Differences in Implicit
708 and Explicit Processing of Emotional Facial Expressions as Revealed by Event-Related Theta
709 Synchronization. *Emotion*, 10(5), 678–687. <https://doi.org/10.1037/a0019175>
- 710 Kogler, L., Müller, V. I., Seidel, E.-M., Boubela, R., Kalcher, K., Moser, E., Habel, U., Gur, R. C.,
711 Eickhoff, S. B., & Derntl, B. (2016). Sex differences in the functional connectivity of the
712 amygdalae in association with cortisol. *NeuroImage*, 134, 410–423.
713 <https://doi.org/10.1016/j.neuroimage.2016.03.064>
- 714 Kreibig, S. D. (2010). Autonomic nervous system activity in emotion: A review. *Biological Psychology*,
715 84(3), 394–421. <https://doi.org/10.1016/j.biopsycho.2010.03.010>
- 716 Kwon, H., Yoon, K. L., Joormann, J., & Kwon, J.-H. H. (2013). Cultural and gender differences in
717 emotion regulation: Relation to depression. *Cognition & Emotion*, 27(5), 769–782.
718 <https://doi.org/10.1080/02699931.2013.792244>
- 719 Lacadie, C. M., Fulbright, R. K., Arora, J., Constable, R., & Papademetris, X. (2008). Brodmann Areas
720 defined in MNI space using a new Tracing Tool in BioImage Suite. *Proceedings of the 14th*
721 *Annual Meeting of the Organization for Human Brain Mapping*, 771.
- 722 Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1999). *International affective picture system (IAPS):*
723 *Instruction manual and affective ratings*.
- 724 Legon, W., Punzell, S., Dowlati, E., Adams, S. E., Stiles, A. B., & Moran, R. J. (2016). Altered
725 Prefrontal Excitation/Inhibition Balance and Prefrontal Output: Markers of Aging in Human
726 Memory Networks. *Cerebral Cortex*, 26(11), 4315–4326. <https://doi.org/10.1093/cercor/bhv200>
- 727 Li, J., Hao, Y., Zhang, W., Li, X., & Hu, B. (2021). Effective connectivity based EEG revealing the
728 inhibitory deficits for distracting stimuli in major depression disorders. *IEEE Transactions on*
729 *Affective Computing*, 1–13. <https://doi.org/10.1109/TAFFC.2021.3054953>

- 730 Li, P., Liu, H., Si, Y., Li, C., Li, F., Zhu, X., Huang, X., Zeng, Y., Yao, D., Zhang, Y., & Xu, P. (2019).
731 EEG Based Emotion Recognition by Combining Functional Connectivity Network and Local
732 Activations. *IEEE Transactions on Biomedical Engineering*, 66(10), 2869–2881.
733 <https://doi.org/10.1109/TBME.2019.2897651>
- 734 Lim, S. I., Woo, J. C., Bahn, S., & Nam, C. S. (2012). The Effects of Individuals' Mood State and
735 Personality Trait on the Cognitive Processing of Emotional Stimuli. *Proceedings of the Human
736 Factors and Ergonomics Society Annual Meeting*, 56(1), 1059–1063.
737 <https://doi.org/10.1177/1071181312561231>
- 738 Lindquist, K. A., & Barrett, L. F. (2008). Emotional complexity. *Handbook of Emotions*, 513–530.
- 739 Lindquist, K. A., & Barrett, L. F. (2012a). A functional architecture of the human brain: Insights from
740 emotion. *Trends in Cognitive Sciences*, 16, 533–554.
- 741 Lindquist, K. A., & Barrett, L. F. (2012b). A functional architecture of the human brain: emerging
742 insights from the science of emotion. *Trends in Cognitive Sciences*, 16(11), 533–540.
743 <https://doi.org/10.1016/j.tics.2012.09.005>
- 744 Lindquist, K. A., Satpute, A. B., Wager, T. D., Weber, J., & Barrett, L. F. (2016). The Brain Basis of
745 Positive and Negative Affect: Evidence from a Meta-Analysis of the Human Neuroimaging
746 Literature. *Cerebral Cortex*, 26(5), 1910–1922. <https://doi.org/10.1093/cercor/bhv001>
- 747 Lindquist, K. A., Wager, T. D., Kober, H., Bliss-Moreau, E., & Barrett, L. F. (2012). The brain basis of
748 emotion: A meta-analytic review. *Behavioral and Brain Sciences*, 35(3), 121–143.
749 <https://doi.org/10.1017/S0140525X11000446>
- 750 Litvak, V., Mattout, J., Kiebel, S., Phillips, C., Henson, R., Kilner, J., Barnes, G., Oostenveld, R.,
751 Daunizeau, J., Flandin, G., Penny, W., & Friston, K. (2011). EEG and MEG Data Analysis in
752 SPM8. *Computational Intelligence and Neuroscience*, 2011, 1–32.
753 <https://doi.org/10.1155/2011/852961>
- 754 Lungu, O., Potvin, S., Tikász, A., & Mendrek, A. (2015). Sex differences in effective fronto-limbic
755 connectivity during negative emotion processing. *Psychoneuroendocrinology*, 62, 180–188.
756 <https://doi.org/10.1016/j.psyneuen.2015.08.012>

- 757 Ma-Kellams, C., & Wu, M. S. (2020). Gender, behavioral inhibition/activation, and emotional reactions
758 to negative natural and social events. *Personality and Individual Differences*, 157.
759 <https://doi.org/10.1016/j.paid.2019.109809>
- 760 MacDonald, A. W., Cohen, J. D., Stenger, A., & Carter, C. S. (2000). Dissociating the Role of the
761 Dorsolateral Prefrontal and Anterior Cingulate Cortex in Cognitive Control. *Science*, 288(5472),
762 1835–1838. <https://doi.org/10.1126/science.288.5472.1835>
- 763 Markus, H. R., & Kitayama, S. (1991). Culture and the self: Implications for cognition, emotion, and
764 motivation. *Psychological Review*, 98(2), 224–253. <https://doi.org/10.1037/0033-295X.98.2.224>
- 765 McRae, K., Ochsner, K. N., Mauss, I. B., Gabrieli, J. J. D. D., & Gross, J. J. (2008). Gender Differences
766 in Emotion Regulation: An fMRI Study of Cognitive Reappraisal. *Group Processes & Intergroup*
767 *Relations*, 11(2), 143–162. <https://doi.org/10.1177/1368430207088035>
- 768 Mesquita, B., De Leersnyder, J., & Boiger, M. (2016). The cultural psychology of emotion. *Handbook of*
769 *Emotions*, 4, 393–411.
- 770 Morawetz, C., Bode, S., Baudewig, J., Kirilina, E., & Heekeren, H. R. (2016). Changes in Effective
771 Connectivity Between Dorsal and Ventral Prefrontal Regions Moderate Emotion Regulation.
772 *Cerebral Cortex*, 26(5), 1923–1937. <https://doi.org/10.1093/cercor/bhv005>
- 773 Motzkin, J. C., Philippi, C. L., Wolf, R. C., Baskaya, M. K., & Koenigs, M. (2015). Ventromedial
774 prefrontal cortex is critical for the regulation of amygdala activity in humans. *Biological*
775 *Psychiatry*, 77(3), 276–284. <https://doi.org/10.1016/j.biopsych.2014.02.014>
- 776 Murata, A., Moser, J. S., & Kitayama, S. (2013). Culture shapes electrocortical responses during emotion
777 suppression. *Social Cognitive and Affective Neuroscience*, 8(5), 595–601.
778 <https://doi.org/10.1093/scan/nss036>
- 779 Nam, C. S. (2020). *Neuroergonomics* (C. S. Nam (ed.)). Springer International Publishing.
780 <https://doi.org/10.1007/978-3-030-34784-0>
- 781 Ochsner, K. N., Bunge, S. A., Gross, J. J., & Gabrieli, J. D. E. (2002). Rethinking feelings: An fMRI
782 study of the cognitive regulation of emotion. *Journal of Cognitive Neuroscience*, 14(8), 1215–
783 1229. <https://doi.org/10.1162/089892902760807212>

- 784 Oldfield, R. C. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory.
785 *Neuropsychologia*, 9(1), 97–113. [https://doi.org/10.1016/0028-3932\(71\)90067-4](https://doi.org/10.1016/0028-3932(71)90067-4)
- 786 Padmala, S., & Pessoa, L. (2008). Affective learning enhances visual detection and responses in primary
787 visual cortex. *Journal of Neuroscience*, 28(24), 6202–6210.
788 <https://doi.org/10.1523/JNEUROSCI.1233-08.2008>
- 789 Park, D. C., & Huang, C. M. (2010). Culture wires the Brain: A cognitive neuroscience perspective. In
790 *Perspectives on Psychological Science* (Vol. 5, Issue 4, pp. 391–400).
791 <https://doi.org/10.1177/1745691610374591>
- 792 Penny, W. D., Stephan, K. E., Mechelli, A., & Friston, K. J. (2004). Comparing dynamic causal models.
793 *NeuroImage*, 22(3), 1157–1172. <https://doi.org/10.1016/j.neuroimage.2004.03.026>
- 794 Pessoa, L. (2018). Understanding emotion with brain networks. *Current Opinion in Behavioral Sciences*,
795 19, 19–25. <https://doi.org/10.1016/j.cobeha.2017.09.005>
- 796 Phan, K. L., Wager, T., Taylor, S. F., & Liberzon, I. (2002). Functional neuroanatomy of emotion: A
797 meta-analysis of emotion activation studies in PET and fMRI. In *NeuroImage* (Vol. 16, Issue 2, pp.
798 331–348). <https://doi.org/10.1006/nimg.2002.1087>
- 799 Phillips, M. L., Ladouceur, C. D., & Drevets, W. C. (2008). A neural model of voluntary and automatic
800 emotion regulation: Implications for understanding the pathophysiology and neurodevelopment of
801 bipolar disorder. In *Molecular Psychiatry* (Vol. 13, Issue 9, pp. 833–857).
802 <https://doi.org/10.1038/mp.2008.65>
- 803 Picard, R. W. (2003). Affective computing: challenges. *International Journal of Human-Computer*
804 *Studies*, 59(1–2), 55–64. [https://doi.org/10.1016/S1071-5819\(03\)00052-1](https://doi.org/10.1016/S1071-5819(03)00052-1)
- 805 Poria, S., Cambria, E., Bajpai, R., & Hussain, A. (2017). A review of affective computing: From
806 unimodal analysis to multimodal fusion. *Information Fusion*, 37, 98–125.
807 <https://doi.org/10.1016/j.inffus.2017.02.003>
- 808 Porrino, L. J., Crane, A. M., & Goldman-Rakic, P. S. (1981). Direct and Indirect Pathways From the
809 Amygdala to the Frontal Lobe in Rhesus Monkeys. In *THE JOURNAL OF COMPARATIVE*
810 *NEUROLOGY* (Vol. 198).

- 811 Power, M., & Dalgleish, T. (2015). *Cognition and Emotion*. Psychology Press.
812 <https://doi.org/10.4324/9781315708744>
- 813 Protopapa, F., Siettos, C. I., Evdokimidis, I., & Smyrnis, N. (2014). Granger causality analysis reveals
814 distinct spatio-temporal connectivity patterns in motor and perceptual visuo-spatial working
815 memory. *Frontiers in Computational Neuroscience*, 8. <https://doi.org/10.3389/fncom.2014.00146>
- 816 Pugh, Z. H., Choo, S., Leshin, J. C., Lindquist, K. A., & Nam, C. S. (2021). Emotion depends on context,
817 culture and their interaction: evidence from effective connectivity. *Social Cognitive and Affective
818 Neuroscience*. <https://doi.org/10.1093/scan/nsab092>
- 819 Ray, R. D., & Zald, D. H. (2012). Anatomical insights into the interaction of emotion and cognition in
820 the prefrontal cortex. In *Neuroscience and Biobehavioral Reviews* (Vol. 36, Issue 1, pp. 479–501).
821 <https://doi.org/10.1016/j.neubiorev.2011.08.005>
- 822 Roy, A. K., Shehzad, Z., Margulies, D. S., Kelly, A. M. C., Uddin, L. Q., Gotimer, K., Biswal, B. B.,
823 Castellanos, F. X., & Milham, M. P. (2009). Functional connectivity of the human amygdala using
824 resting state fMRI. *NeuroImage*, 45(2), 614–626. <https://doi.org/10.1016/j.neuroimage.2008.11.030>
- 825 Rubin, L. H., Yao, L., Keedy, S. K., Reilly, J. L., Bishop, J. R., Carter, C. S., Pournajafi-Nazarloo, H.,
826 Drogos, L. L., Tamminga, C. A., Pearlson, G. D., Keshavan, M. S., Clementz, B. A., Hill, S. K.,
827 Liao, W., Ji, G. J., Lui, S., & Sweeney, J. A. (2017). Sex differences in associations of arginine
828 vasopressin and oxytocin with resting-state functional brain connectivity. *Journal of Neuroscience
829 Research*, 95(1–2), 576–586. <https://doi.org/10.1002/jnr.23820>
- 830 Rukavina, S., Gruss, S., Hoffmann, H., Tan, J.-W., Walter, S., & Traue, H. C. (2016). Affective
831 Computing and the Impact of Gender and Age. *PLOS ONE*, 11(3), e0150584.
832 <https://doi.org/10.1371/journal.pone.0150584>
- 833 Rukavina, S., Gruss, S., Tan, J.-W., Hrabal, D., Walter, S., Traue, H. C., & Jerg-Bretzke, L. (2013). *The
834 Impact of Gender and Sexual Hormones on Automated Psychobiological Emotion Classification*
835 (pp. 474–482). https://doi.org/10.1007/978-3-642-39342-6_52
- 836 Sato, W., Kochiyama, T., Yoshikawa, S., & Matsumura, M. (2001). Emotional expression boosts early
837 visual processing of the face: ERP recording and its decomposition by independent component

- 838 analysis. *Neuroreport*.
839 [http://journals.lww.com/neuroreport/Abstract/2001/03260/Emotional_expression_boosts_early_vis](http://journals.lww.com/neuroreport/Abstract/2001/03260/Emotional_expression_boosts_early_visual.19.aspx)
840 [ual.19.aspx](http://journals.lww.com/neuroreport/Abstract/2001/03260/Emotional_expression_boosts_early_visual.19.aspx)
- 841 Satpute, A. B., & Lindquist, K. A. (2019). The Default Mode Network's Role in Discrete Emotion.
842 *Trends in Cognitive Sciences*, 23(10), 851–864. <https://doi.org/10.1016/j.tics.2019.07.003>
- 843 Schmitt, D. P. (2015). *The Evolution of Culturally-Variable Sex Differences: Men and Women Are Not*
844 *Always Different, but When They Are...It Appears Not to Result from Patriarchy or Sex Role*
845 *Socialization* (Issue February). https://doi.org/10.1007/978-3-319-09384-0_11
- 846 Sharbrough, F., Chatrian, G., Lesser, R., Luders, H., Nuwer, M., & Picton, T. (1991). American
847 Electroencephalographic Society Guidelines for Standard Electrode Position Nomenclature.
848 *Journal of Clinical Neurophysiology*. <https://doi.org/10.1097/00004691-199104000-00007>
- 849 Shi, Y., Liu, W., Liu, R., Zeng, Y., Wu, L., Huang, S., Cai, G., Yang, J., & Wu, W. (2019). Investigation
850 of the emotional network in depression after stroke: A study of multivariate Granger causality
851 analysis of fMRI data. *Journal of Affective Disorders*, 249, 35–44.
852 <https://doi.org/10.1016/j.jad.2019.02.020>
- 853 Siegel, E. H., Sands, M. K., Van den Noortgate, W., Condon, P., Chang, Y., Dy, J., Quigley, K. S., &
854 Barrett, L. F. (2018). Emotion fingerprints or emotion populations? A meta-analytic investigation
855 of autonomic features of emotion categories. *Psychological Bulletin*, 144(4), 343–393.
856 <https://doi.org/10.1037/bul0000128>
- 857 Stevens, J. S., & Hamann, S. (2012). Sex differences in brain activation to emotional stimuli: A meta-
858 analysis of neuroimaging studies. *Neuropsychologia*, 50(7), 1578–1593.
859 <https://doi.org/10.1016/j.neuropsychologia.2012.03.011>
- 860 Suzuki, K., Takei, N., Kawai, M., Minabe, Y., & Mori, N. (2003). Is Taijin Kyofusho a Culture-Bound
861 Syndrome? *American Journal of Psychiatry*, 160(7), 1358–1358.
862 <https://doi.org/10.1176/appi.ajp.160.7.1358>
- 863 The MathWorks. (2004). *MATLAB The Language of Technical Computing*.
864 <https://doi.org/10.1007/s10766-008-0082-5>

- 865 Toga, A. W., & Thompson, P. M. (2003). Mapping brain asymmetry. *Nature Reviews Neuroscience*,
866 4(1), 37–48. <https://doi.org/10.1038/nrn1009>
- 867 Vogt, T., & André, E. (2006). Improving automatic emotion recognition from speech via gender
868 differentiation. *Proceedings of the 5th International Conference on Language Resources and*
869 *Evaluation, LREC 2006*, 1123–1126.
- 870 Vuilleumier, P., & Driver, J. (2007). Modulation of visual processing by attention and emotion:
871 Windows on causal interactions between human brain regions. *Philosophical Transactions of the*
872 *Royal Society B: Biological Sciences*, 362(1481), 837–855. <https://doi.org/10.1098/rstb.2007.2092>
- 873 Wilson-Mendenhall, C D, Barrett, L. F., & Barsalou, L. W. (2013). Neural evidence that human emotions
874 share core affective properties. *Psychological Science*, 24(6), 947–956.
875 <https://doi.org/10.1177/0956797612464242>; [10.1177/0956797612464242](https://doi.org/10.1177/0956797612464242)
- 876 Wilson-Mendenhall, Christine D., Barrett, L. F., Simmons, W. K., & Barsalou, L. W. (2011). Grounding
877 emotion in situated conceptualization. *Neuropsychologia*, 49(5), 1105–1127.
878 <https://doi.org/10.1016/j.neuropsychologia.2010.12.032>
- 879 Wittenberg, E., Kim, N. Y., & Nam, C. S. (2017). Executive function updating level modulates
880 connectivity network between brain regions in alpha band. *Proceedings of the Human Factors and*
881 *Ergonomics Society Annual Meeting*, 61(1), 49–50. <https://doi.org/10.1177/1541931213601507>
- 882 Wood, W., & Eagly, A. H. (2002). A cross-cultural analysis of the behavior of women and men:
883 Implications for the origins of sex differences. *Psychological Bulletin*, 128(5), 699–727.
884 <https://doi.org/10.1037/0033-2909.128.5.699>
- 885 Yuan, J., Tian, Y., Huang, X., Fan, H., & Wei, X. (2019). Emotional bias varies with stimulus type,
886 arousal and task setting: Meta-analytic evidences. *Neuroscience & Biobehavioral Reviews*, 107,
887 461–472. <https://doi.org/10.1016/j.neubiorev.2019.09.035>
- 888 Zhang, W., Suo, T., Zhang, P., Zhao, C., Liao, C., Zhang, L., & Li, H. (2017). Temperamental Effortful
889 Control Modulates Gender Differences in Late Positive Potentials Evoked by Affective Pictures in
890 Adolescents. *Developmental Neuropsychology*, 42(3), 220–230.
891 <https://doi.org/10.1080/87565641.2017.1315806>

- 892 Zhao, Q., Neumann, D. L., Cao, Y., Baron-Cohen, S., Yan, C., Chan, R. C. K., & Shum, D. H. K. (2019).
893 Culture-sex interaction and the self-report empathy in Australians and mainland Chinese. *Frontiers*
894 *in Psychology*, *10*(MAR), 1–15. <https://doi.org/10.3389/fpsyg.2019.00396>
- 895 Zhao, Q., Neumann, D. L., Yan, C., Djekic, S., & Shum, D. H. K. (2021). Culture, Sex, and Group-Bias
896 in Trait and State Empathy. *Frontiers in Psychology*, *12*(April).
897 <https://doi.org/10.3389/fpsyg.2021.561930>
- 898

899 Zachary H. Pugh received a Bachelor's degree in anthropology from the University of North Carolina at
900 Chapel Hill, 2011. He is currently a doctoral student in the Psychology Department of North Carolina
901 State University. His research interests include distributed cognition and applied cognitive psychology.

902

903 Jiali Huang Jiali Huang received a Bachelor's degree in Industrial Engineering from Shandong
904 University, Jinan, China, in 2017. She is currently a doctoral student in the Edward P. Fitts Department
905 of Industrial and Systems Engineering. Her research interests include Dynamic Causal Modeling (DCM)
906 and its usage in human-automation interaction and neuroergonomics.

907

908 Joseph C. Leshin received a Bachelor's degree with high honors in Psychology from Cal Poly, San Luis
909 Obispo, in 2012, and is currently a doctoral student at the University of North Carolina at Chapel Hill. He
910 takes both a neuroscientific and social psychological approach in identifying mechanisms that give rise to
911 individual differences in emotion experience and emotion regulation. His work is funded by a Graduate
912 Research Fellowship from the National Science Foundation.

913

914 Kristen A. Lindquist Kristen Lindquist received a Bachelor's degree with high honors in Psychology and
915 English from Boston College, Chestnut Hill, MA, in 2004, and a PhD degree in Psychology from Boston
916 College, Chestnut Hill, MA in 2010. From 2010 to 2012, she was a Mind/Brain/Behavior postdoctoral
917 fellow in the Psychology Department at Harvard University, Cambridge, MA, the Neurology Department
918 at Harvard Medical School, Boston, MA, and was affiliated with the Martinos Center for Biomedical
919 Imaging, Charlestown, MA. She is currently an Associate Professor of Psychology and Neuroscience at
920 the University of North Carolina, Chapel Hill, NC, a faculty member of the Biomedical Research
921 Imaging Center at the University of North Carolina School of Medicine, Chapel Hill, NC and an affiliate
922 of the Neurobiology Curriculum at the University of North Carolina School of Medicine, Chapel Hill,
923 NC. She is director of the Carolina Affective Science Lab, which examines the functional neurobiology
924 of emotion across the lifespan and culture. Dr. Lindquist has authored or coauthored more than 70
925 scientific articles, is a fellow of the Society for Experimental Social Psychology and was named a Rising

926 Star in Psychological Science by the Association for Psychological Science. Her work is currently funded
927 by the National Science Foundation and National Institutes of Health.

928

929 Chang S. Nam received a PhD degree in Industrial and Systems Engineering from Virginia Tech,
930 Blacksburg, VA in 2003. He is currently a Professor of Industrial and Systems Engineering at North
931 Carolina State University, a faculty member of the Biomedical Research Imaging Center at the
932 University of North Carolina School of Medicine, Chapel Hill, NC and an affiliate of the Department of
933 Biomedical Engineering as well as the Department of Psychology at North Carolina State University. He
934 is director of the Brain-Computer Interfaces and Neuroergonomics Lab. Dr. Nam has authored or
935 coauthored more than 100 scientific articles, edited four books, is a fellow of the Society for the Human
936 Factors and Ergonomics Society. Currently, Dr. Nam serves as the Editor-in-Chief of the journal Brain-
937 Computer Interfaces.