





Effective amygdala-prefrontal connectivity during emotion regulation: a meta-analysis of psychophysiological interactions

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Introduction

In recent years, a myriad of neuroimaging studies has investigated the neural basis of emotion regulation (ER), and substantial progress has been made toward building neurally plausible models of ER¹. However, single studies usually provide limited insight into the function of specific brain regions. Thus, to better understand the role of the amygdala in emotion regulation, we performed coordinate-based meta-analysis on studies of emotion regulation related connectivity of the amygdala which used functional magnetic resonance imaging (fMRI) and psychophysiological interaction (PPI) analysis².

Records identified

Records identified through database searching (n=289)

Additional records identified through other sources (n=15)

Records after duplicates removed and screened on the title and abstract

Distinct records selected (n= 132)

Records excluded (n=158)

Full-text articles assessed for eligibility

Studies fulfilling inclusion criteria (n=11)

Full-text articles excluded (n=120)

Studies included in Meta-Analysis						
Study	Year	n[p]	Strategy	Goal	Valence	Seed
Banks et al.	2007	14	reapp	dec	neg	left
Chen et al.	2017	47	supp	dec	neg	right
Erk et al.	2010	17	reapp	dec	neg	left
Herwig et al.	2019	11	reapp	dec	neg	right
Kanske et al.	2011	30	reapp + distr	dec	neg + pos	left
Li et al.	2018	33	reapp	inc	pos	averaged
Morawetz et al.	2017	23	reapp	dec + inc	neg	left
Paschke et al.	2016	93/86	reapp	dec	neg	left + right
Payer et al.	2012	10	reapp	dec	neg	averaged
Sripada et al.	2014	49	reapp	dec	neg	right
Winecoff et al.	2011	42	reapp	dec	neg+pos	left+right

Data extraction

Analysis: n[experiments]= 17 n[foci] =230 n[participants]=596

Fig. 1: Flow Diagram outlining the study selection process. Studies included in the meta-analysis are described with regard to the investigated emotion regulation strategy, the regulation goal, the valence of the used stimuli and the seed region of the PPI analyses. n, number of studies; reapp, reappraisal; supp, suppression; distr, distraction; dec, decrease; inc, increase; neg, negative; pos, positive; L, left amygdala seed; R, right amygdala seed; av., left and right amygdala averaged as seeds.

Methods

- Literature research was conducted using PubMed (www.pubmed.com)
- Search terms: "emotion regulation" "affective regulation", "reappraisal", "fMRI", "functional magnetic resonance imaging", "functional MRI", "effective connectivity", "functional connectivity", "PPI" and "psychophysiological interaction analysis"
- Time frame: 1st of January 2000 to 25th of February 2020 (**Fig.1**)
- Meta-analysis on experiments reporting PPI main effects and experiments that integrated individual difference factors (emotion regulation success or self-control)
- activation likelihood estimation (ALE) algorithm for coordinate-based quantitative meta-analyses of neuroimaging results as implemented in GingerALE 3.0.2³
- Seed region: Amygdala

Results

The meta-analysis revealed convergent connectivity with the amygdala during emotion regulation compared to a control condition in three regions:

- (1) the left inferior frontal gyrus (IFG)/vIPFC (BA47; x = -34, y = 34, z = -9, Volume [mm³] = 904)
- (2) the medial frontal gyrus (MFG)/dmPFC (BA8; x = 4, y = 28, z = 46, Volume [mm³] = 768)
- (3) the left claustrum (x = -33, y = 4, z = 0, Volume [mm³] = 736) (**Fig. 2**)

vIPFC/IFG dmPFC/MFG Claustrum x=-34 wipfC/MFG Claustrum y=4

Fig. 2: Results of the meta-analysis revealed convergent connectivity between the amygdala and 3 regions during emotion regulation.

Conclusion

- The meta-analysis revealed convergent task-modulated coupling of the amygdala with prefrontal cortex regions such as the dmPFC and the left vIPFC, as well as the left claustrum.
- Both prefrontal regions have been implicated in emotion regulatory processes, specifically, the vIPFC in language processes and the dmPFC in the attribution of mental states. The claustrum cluster presumably represents an integral hub during the regulation of emotion.
- Our findings support the idea of dynamic modulation of connectivity between emotion generative and regulatory systems during the cognitive control of emotions, and highlight the robustness of task-modulated prefrontal-amygdala coupling.

References

- ¹ Morawetz, C., et al. (2017). *Neuroscience and Biobehavioral Reviews, 72*, 111-128.
- ² Friston, K.J., et al. (1997). *Neurolmage*, *6*(3), 218-229.
- ³ Eickhoff, S.B., et al. (2012). *NeuroImage*, *59*(3), 2349-2361.